THE HERBARIUM: PAST, PRESENT, AND FUTURE[1]

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The herbarium as an institution dates back more than four centuries, but the origins of plant collecting for medical and proto-scientific purposes trace back even further to the time of the medieval herbalists. To some of today's biologists the herbarium is an anachronism in the modern scientific world, and their voice of reproach has seemed to grow ever more deafening, especially to the ears of the curator. In response have come some eloquent defenses of the herbarium and its historical significance to science and human welfare (e.g., Beaman *et al.* 1965, Cronquist 1966). Notwithstanding frequent optimistic predictions, however, today the herbarium faces critical challenges to its future existence. Quantitative gains too often are being mistaken for progress and good health, while in fact the physical facilities, staff, operational procedures, collection strategy, and intellectual *raison d'être* of the herbarium are not

[1] This paper, given at the symposium under the title "The Future of the Herbarium," has been expanded greatly in the statistical portions dealing with the past and present of the herbarium. "A herbarium," as Lawrence (1951) defines it, "is a collection of plant specimens that usually have been dried and pressed, are arranged in the sequence of an accepted classification [can be purely alphabetical], and are available for reference or other scientific study." Cronquist (1966) would add that "a herbarium can be a very useful teaching aid or an absorbing hobby. . . ." It is beyond the intent of this paper to review the extensive and widely scattered literature on the history, philosophy, apologetics, and methodology of herbaria.

[2] I am deeply indebted to Elaine R. Shetler and Nancy L. Howard for help in abstracting, keypunching, and compiling the statistics, and to James J. Crockett and Shigeko I. Rakosi, Smithsonian Information Systems Division, for taking care of the computer programming and processing. Dr. John H. Beaman, Curator of the Beal-Darlington Herbarium of Vascular Plants, has kindly cooperated in supplying information on the Michigan State University Herbarium. Acknowledgment is due also to Mildred J. Davenport and Betty Scott for assistance on the manuscript. Financial support was provided by a grant (Sg0621054/C-1) from the Smithsonian Research Awards Program.

keeping pace with the times. Future prospects are being forecast on the basis of the past or present significance of the herbarium without due regard for its changing role. Consequently, the prognoses are at best too optimistic and at worst delusive or irrelevant.

In many respects, to be sure, the ills of the modern herbarium are only symptomatic of the greater malaise that besets the whole of classical botany and indeed biology (Bonner 1963, Laetsch 1963, Shetler 1963, Smith 1964, Engledow 1968). On the one hand, the traditional disciplinary approach to biology, which has tended to partition it into botany and zoology and then into kinds of plants and animals, is giving way to the levels-of-organization approach, which is topical and cuts across the classic groupings of organisms. On the other hand, descriptive biology at the higher levels of organization is becoming unfashionable and is being supplanted aggressively in curriculums and graduate research programs by descriptive and experimental molecular biology. Fortunately there are scientists who understand the importance of descriptive biology at the higher levels and can counteract the trend to supplant rather than complement such biology with molecular biology (e.g., Mayr 1968).

Faced with the crisis in classical biology, the museum, that citadel of descriptive biology of which the herbarium is but a special case, is remarkably healthy and viable today even in many universities. In some instances, in fact, other, seemingly more favored scientific facilities have taken second place to the museum. There is always the overwhelming physical reality of a large collection of specimens that cannot be ignored easily, although it is precisely this attribute that increasingly has become a negative factor whenever the future of a museum is at stake.

Whether the omens for the future seem favorable or unfavorable the time has arrived for curators to take a realistic look at the current plight of the herbarium and to make some frank assessments of future needs and prospects. This must be done at the risk of a misuse of findings among our critics. I hope that this paper will provoke more dialogue among herbarium curators, administrators, and plant systematists at large con-

cerning the future of the herbarium and thereby lead to a more exhaustive study of the question than I am able to offer.

Source Of Statistics

The herbarium fraternity, thanks to the pioneer efforts of Professor Lanjouw (*see* "Introduction," Lanjouw and Stafleu 1959), has been polling itself for many years concerning herbarium resources. This work has been carried out under the auspices of the International Bureau for Plant Taxonomy and Nomenclature of the International Association for Plant Taxonomy (IAPT), with headquarters in Utrecht, Netherlands. The results have been published in *Index Herbariorum, Part I: The Herbaria of the World* (hereinafter abbreviated *I.H.*), now in its fifth edition (Lanjouw and Stafleu 1964), with a sixth due this year. This compilation, though it has obvious shortcomings, is invaluable and unique: no other group of biologists, to my knowledge, has such a concise, worldwide digest of its research collections. Other, complementary reference guides published by the IAPT are an index to plant collectors (Lanjouw and Stafleu 1954, 1957), an index to institutional wood collections (Stern 1967), a directory of plant taxonomists (De Roon 1958), and a directory of botanical gardens (Howard *et al.* 1963). Together these reference works constitute a gold mine of information that could be exploited more fully if they were computerized for easy permutation and comparison of the data. Perhaps this will be done in future editions.

My analysis is based largely on statistics abstracted from the most recent edition (5th) of *I.H.* and permuted by computer. Dated 1964, this edition is effective only through 1963, thereby providing a 5-year supplement (1959–63 inclusive) to the fourth edition (Lanjouw and Stafleu 1959). Ten data fields were formatted on an IBM card, and a card was keypunched for each herbarium treated in the text. Geographic data were supplemented from a world atlas. The ten fields are: (1) official herbarium abbreviation (e.g., US for U. S. National Herbarium, Smithsonian Institution),[3] (2) city, (3) state or prov-

[3] In the discussion that follows, I sometimes have given only the standard abbreviation of a herbarium in lieu of the full name, so that the general reader will be spared meaningless details. With the abbreviation, taxonomists who are interested can look up the specifics in *I.H.*, which they usually have close at hand.

ince (only for Australia, Brazil, Canada, China, Great Britain, India, Mexico, USA, USSR), (4) country, (5) continent or region, (6) year of founding, (7) number of specimens, (8) number of staff, (9) organizational status (university, government, private), and (10) type of plants (phanerogams, cryptogams, general).

With the aid of a Honeywell 1250 computer, a directory (Shetler *et al.* 1968) was produced indexing the herbaria alphabetically by: (1) abbreviation; (2) city; (3) country and state or province within country; (4) continent, country within continent, and state or province within country; (5) organizational status and country within status; and (6) type of plants and country within type. Also, the herbaria were ordered by (7) year of founding, (8) size of collection, and (9) size of staff. In the process of indexing, certain statistics were computed by machine, and still other statistics have been computed manually from the printout for the purposes of this paper.

Of the 1,188 herbaria listed in *I.H.* (1964) at least by name and abbreviation, only 941 are actually treated or mentioned in the text, and 8 of these (BM-SL, G-DC, ND-G, SAM, SARF, STE-VB, TM, TRV) are incorporated with other herbaria and do not have separate statistics.[4] This leaves 933 herbaria for which at least some data are given. Unless otherwise indicated, all statistics and comparisons are based on an analysis of data provided for these 933 herbaria.

Index Herbariorum is intended to cover only public, institutional herbaria. Collections in the hands of private individuals are not considered part of the public domain of science and are not assigned standard abbreviations (mark of official recognition) nor included in *I.H.* The hundreds, probably thousands, of private herbaria in the world are usually small, seldom exceeding a few hundred or thousand specimens. In at least one case, however, a private collection is known to number about 150,000 specimens, a not insignificant herbarium. Of

[4] The alphabetical index to herbarium abbreviations registers 247 herbaria omitted from the text, all but one (GUA) being small British institutional herbaria taken from Kent's book (1957) and listed in *I.H.* to provide conveniently their official abbreviations. Twelve of the 941 herbaria treated or mentioned in the text are not included in the index: BM-SL, CHIS, CHISA, G-DC, KL, KLA, KLU, KRA, ND-G, SARF, TENN, TM.

course many institutional herbaria began as private collections.

Even as a register of public herbaria, *I.H.* still falls short of completeness after 30 years of data-collecting and updating. Of the 167 herbaria reporting for the first time in the 5th edition, which represent about 18% of the 933 herbaria treated, only 13 report a founding date in the years (1959–63) since the 4th edition appeared. Thus even in the latest edition of *I.H.* over 16 percent of the main entries (92 percent of new entries) are entries that should have appeared already in the 4th edition if not before. The real total of public institutional herbaria has not been approached. We know in the case of Great Britain, thanks to Kent's book (1957), that almost five times as many institutional herbaria have escaped full treatment in *I.H.* as have been treated (246:50). Every country, no doubt, has its own small, unnoticed herbaria in municipal, county, and state or provincial museums, schools, and parks. The United States, for example, has many, often quite valuable though local herbaria in national parks. For the most part, these obscure herbaria, which so far have either failed to respond to questionnaires or have escaped the notice of the compilers of *I.H.*, are small and inactive with respect to the national and international commerce of plant taxonomy. It is likely that the number of scientifically important herbaria in the world is about 1,000, i.e., approximately the number now treated in *I.H.* Doubtlessly some important herbaria, particularly in the USSR, China, and Southeast Asia, have not yet reported, but at the same time some of the tiny herbaria already treated in *I.H.* are relatively unimportant to the pursuit of systematics. Having said this, I hasten to add that in a real, if relative, sense all herbaria are scientifically important. It is to be hoped that eventually *I.H.* can be a complete worldwide register of institutional herbaria. If the 5:1 ratio of unreported to reported herbaria of Great Britain were to hold throughout the world, then there could be as many as 5,000 institutional herbaria. If Kent's data are a safe guide to the size of the smaller, unreported herbaria of the world, then such herbaria have anywhere from 200 to 75,000 specimens and average almost 5,000 specimens/herbarium. At this rate, 1–1.5 million specimens should be added to

the *I.H.* figure just for Great Britain, and on a worldwide scale this could mean an additional 18–20 million specimens.

The problem of missing data is bothersome because many herbaria did not report complete information. Number of specimens was reported by 78 precent of the 933 herbaria and year of founding by 79 percent, while 85 percent listed the names of one or more staff members. Perhaps some of the 15 percent not listing staff in fact do not have any staff. Except where otherwise indicated, the statistics of this paper are based on the herbaria actually reporting and are not extrapolated to account for all 933 herbaria treated in *I.H.*, to say nothing of the 247 mentioned but not treated in *I.H.* or of any estimated world total of herbaria. It should be kept in mind, therefore, that in reality the figures would be higher, perhaps much higher, in all categories if data were available for all public herbaria. The bias of missing data probably affects the statistics for most countries about the same, but there are some notable exceptions. The herbarium resources of mainland China cannot be assessed realistically because 73 percent of the entries in *I.H.* for Chinese herbaria (excluding Taiwan) do not include number of specimens or the names of staff. For the USSR, only 58 percent of the included herbaria report staff and only 60 percent report number of specimens. French herbaria report number of specimens in even fewer cases (57 percent). Some of the smaller countries have not reported any staff or specimen totals.[5]

Concerning the reliability of the data in *I.H.*, the questions, When is a herbarium actually founded?, What is a specimen?, and, Who is a staff member?, naturally arise.

Establishing the founding date of a herbarium can be a quite subjective matter. The U. S. National Herbarium,[6] for example,

[5] Countries not reporting any staff (total number of herbaria in parentheses): British Honduras (1), Ecuador (2), Greenland (1), Lebanon (1), Nicaragua (1), Paraguay (1), Ryukyu Islands (1), and Seychelles (1); countries not reporting any specimen totals: Azores (1), British Solomon Islands (1), Ecuador (2), Greenland (1), Korea (2), Nicaragua (1), Paraguay (1), Ryukyu Islands (1), and Tunisia (1).

[6] The U. S. National Herbarium, as the Smithsonian's plant collection has long been designated in the international taxonomic fraternity, is administered by the Department of Botany of the Institution's National Museum of Natural History. Technically speaking, therefore, "U. S. National Herbarium" is a term of convenience for the collections themselves and not an official organization with a staff and administrative status. For practical purposes, however, it can be so regarded in many contexts.

gives a founding date of 1868 in *I.H.* This was the year when a Smithsonian herbarium was organized in Washington, D. C., under the care of the U. S. Department of Agriculture, but shortly after its founding in 1846 the Smithsonian Institution had already come into possession of plant collections made under federal auspices as early as 1840 (Stern 1966). It was not until 1894, however, that the U. S. National Herbarium was officially established at the Smithsonian. A further example is the herbarium of the Komarov Botanical Institute in Leningrad, said in *I.H.* to have been founded in 1823, but which actually was an outgrowth of collections started almost at the inception in 1714 of the forerunner medical garden (*cf.* Shetler 1967, Lipschitz and Vassilczenko 1968). In *I.H.*, the founding dates of the medical garden and herbarium are distinguished from each other. Even when, as in this case, the distinction is made in *I.H.* between the founding dates of the herbarium and its mother institution, choice of starting point may be entirely subjective.

The overwhelming majority of specimens reported in *I.H.* are of the conventional herbarium type, but it is clear that other types of specimens (fossils; wood samples; fossil or wood thin sections; pollen, spore, and other anatomical microscope slides) frequently are included in the totals. Cryptogamic specimens are especially problematic. There is no uniform way of counting them; yet generally they are not tallied separately in *I.H.* One must assume that the confounding effects of cryptogamic and other kinds of specimens are spread over all herbaria.

To judge by the few herbaria giving exact figures for totals, one would conclude that only about 3 percent of the world's herbaria actually maintain precise counts of specimens held. Furthermore, it is not possible to know in any given case how many of the specimens of the total are mounted as opposed to unmounted or available for consultation as opposed to being in storage and unavailable.

The criteria for reporting staff obviously varied from one herbarium to another. In general, only professional curatorial-research staff are listed, but some universities and research institutes have reported whole faculties or groups of faculties, so inflating their actual staffs that it is impossible to know how

many persons play an active role in the herbarium. Other institutions have included directors or administrators who have nothing to do with the herbarium and in fact may not even be botanists, while still others have included technical staff such as preparators. In the future, herbaria should be encouraged to report total number of technical and clerical staff, without names, and to distinguish, as some herbaria have already done, between active curators on the one hand and associated researchers and emeritus or honorary curators on the other hand, so that an accurate picture of the world's professional manpower devoted to the maintenance of herbarium collections can be ascertained.

Lacking any sound basis for consistently distinguishing between different kinds of staff in *I.H.*, I have simply counted all persons listed for each herbarium. If we can assume that the excesses of one are cancelled by the deficiencies of another, then we can assume that the total figures yield a reasonably fair report of professional curatorial manpower in the world's herbaria. Given this rough level of manpower estimation, I have ignored cases of duplication. About 2 percent of the names appear twice, but often it is not possible to know whether the curator was holding two positions or had moved to another herbarium too recently for his name to have been removed from the roster of the first herbarium.

Notwithstanding its limitations and shortcomings, *Index Herbariorum* provides an excellent statistical abstract of the world's herbarium resources for which the compilers must be given full credit. Even though the data in specific cases may be suspect, this should not invalidate collective statistics and comparisons unless there is evidence of systematic bias. I hope that my paper will have the positive effect of stimulating curators to help in correcting and refining the data in future editions of *I.H.* where necessary.

To supplement the data of *I.H.* and make my analysis more vivid and contemporary, I have selected two American herbaria for brief case study. As an example of a university herbarium, I take the Michigan State University (MSU) Herbarium. A recent symposium, held about the time when the 5th edition of *I.H.* was issued, focussed attention on the MSU Herbarium

and the problems of university herbaria in general. This herbarium, with its approximately 200,000 specimens, characterizes active university herbaria of small to moderate size. The U. S. National Herbarium will serve as my example of a large non-university herbarium. For statistics on the National Herbarium I have drawn freely from the excellent status reports of the Smithsonian's Department of Botany that were prepared for internal purposes recently by Stern (1966) and Hale (1967).

Growth Of World's Herbarium Resources

All of the tables (1–16), compiled from the 5th edition of *I.H.* (1964), are placed at the end of the paper.

Chronology of Herbarium Founding

The first institutional herbarium was founded about 425 years ago in 1545 at the University of Padua in Italy[7] (*see* Tables 5–12). Only 12 more herbaria were to be founded during the next 200 years, including four others in the 16th century and four in the 17th century. Among the latter were two, formed in 1635, which today are among the world's most renowned herbaria, namely, the phanerogamic (P) and cryptogamic (PC) herbaria of the *Muséum National d'Histoire Naturelle* in Paris. The first half of the 18th century saw only four herbaria established, but the second half brought a minor burst of 32 foundings. Several of the great herbaria of Europe and the British Isles took origin during this period. Thus herbarium formation did not begin in earnest until about 1750. The year 1753, when Linnaeus published his revolutionary *Species Plantarum*, was only the second in history in which two herbaria were founded (British Museum, London; University of Vienna, Austria), and the decade of the 1750s was the first in history in which more than two (five) herbaria were formed. Henceforth, the number of herbaria formed per decade, plotted in Fig. 1 for every decade from 1750–59 to 1950–59, began to rise, only twice dipping below the level of the 1750s. Of the 21 decades from the 1540s to the 1740s, by contrast, there were 10

[7] The founding date for the university herbarium at Pisa, Italy, is given in *I.H.* as "before 1850," but the botanic garden of the university, which may have maintained a dried plant collection early in its history, is said to have originated in 1543. The analysis deals, of course, only with herbaria in existence.

in which no herbarium was founded, 9 in which only a single herbarium was formed, and 2 (1560s, 1630s) when two herbaria were founded.

Prior to 1750, only one herbarium (Mauritius, 1737) had been formed outside the continent of Europe. Several herbaria came into being in the British Isles during the next 50 years, and the first herbarium of the New World was founded in 1772 at Winston-Salem, North Carolina, in the United States. A year later the second and only other New World herbarium to be founded prior to the 19th century was formed at Charleston, South Carolina, where the collections of Stephen Elliott, pioneer botanist of the Carolinas, have been kept. Neither of these herbaria ever advanced far. The first *principal* herbarium of the United States, though actually the fourth to be founded in this country, was organized in 1812 at the Academy of Natural sciences of Philadelphia (given as first American herbarium by Jones and Meadows 1948). In Asia, the first herbarium was established in 1793 at Calcutta, India, and a second was not formed until almost 25 years later. The first herbaria of South America and Africa were not formed until the 1800s, in 1808 (Rio de Janeiro, Brazil, RB) and 1855 (Cape Town, South Africa, SAM), respectively.

Up to the year 1800, i.e., for over 250 years, only 45 herbaria had been founded, 94 percent of these in Europe and the British Isles. During the next 50 years (1800–49) the pace of founding quickened markedly, and 76 herbaria, about 1.5/year, were formed. Well over half of these were formed in Europe and the British Isles, but a dozen were founded in North America and a handful elsewhere. The rise and spread of the herbarium as a scientific institution had really begun. Thus, while only 13 herbaria had been established in the entire world prior to 1750, the British Isles and North America each had about this many by 1850. By contrast, however, Asia, the Australasian-Pacific Island region, and South America were not to achieve about a dozen herbaria each until 1900, more than 350 years after the very first herbarium was organized, and Africa could not claim this milestone until the first decade of the present century had passed.

During the 1800s, 270 (37 percent) of the present 933 herbaria

were established, at an average rate of 2.7/year. By the late 1830s one or more herbaria were being created virtually every year, and, according to the official record (*I.H.*), over the 125-year period from 1839 to 1963 there have been only 5 years (1841, 1843, 1851, 1866, 1961), including only one in the present century, when new herbaria have not been founded. The real explosion in herbarium building has come during the present century. Thus far (1900–63) 420 herbaria, 57 percent of the total number, have been founded, averaging 6.6/year, which is more than twice the rate for the 19th century and exactly triple the overall rate (2.2/year) for the whole 419-year period (1545–1963). Of these 419 years there have been 239, of which 234 occurred prior to 1839, when not a single new herbarium was formed.

The golden age of herbarium-founding began about the middle of the 19th century and lasted for about 100 years (Fig. 1). The 1850s witnessed a sharp upswing to 30 in the number of herbaria founded per decade, and from there the general trend was upward until the 1920s when 91 herbaria, the all-time high for a single decade, were formed. The peak year was reached in 1890 when 20 herbaria were founded. There have been only 13 other years in history, all in the 20th century, when 10 or more herbaria were founded in a single year; these vintage years, in order of decreasing number of herbaria formed, have been: 1930 (15 herbaria); 1920 (14); 1935, 1947 (13); 1918, 1925, 1946 (12); 1900, 1922, 1923, 1924, 1950 (11); and 1932 (10). Since the 1920s, the founding of new herbaria has declined sharply.

The 100-year herbarium boom has coincided roughly with a similar golden age of exploration and description in plant systematics and biology generally, which was initiated by the great pioneer biologists of the late 18th and 19th centuries and, it appears, is now drawing to a close in mid-20th century. A pivotal factor in the United States, both in the flourishing of explorative-descriptive biology and in the rise of the herbarium, was the passage by the U. S. Congress of the first (1862) and second (1890) Morrill acts (sponsored by Representative Justin Smith Morrill), providing for the establishment and support of land-grant colleges to promote, among other studies, the agri-

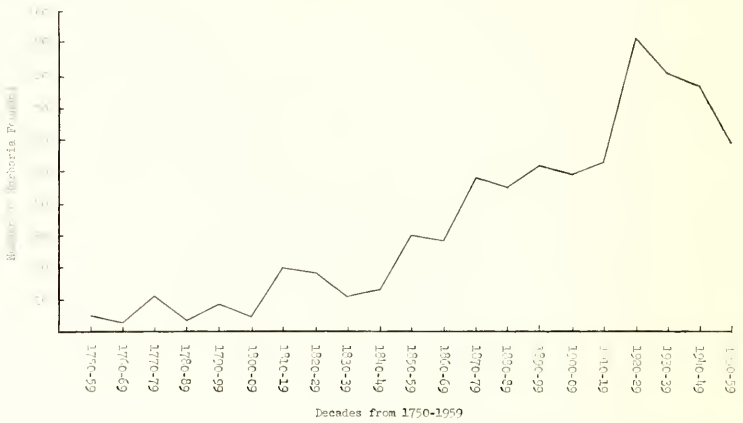

Fig. 1. Number of Herbaria Founded Per Decade from 1750 to 1960.

cultural sciences. Some of the most outstanding herbaria in the United States today are to be found in land-grant institutions tracing their starts to this legislation. Although the influence and support of the land-grant acts continue, reinforced by additional legislation as recently as 1960, the impetus of the agricultural college, which so profoundly affected the course of herbarium development in America, was largely dissipated after the first few decades of the present century. This development in America must be regarded as having influenced the worldwide trend as well, given that the USA can claim nearly a quarter of the world's herbaria today.

Herbarium-founding has by no means stopped today, despite the sharply declining rate since the 1920s. If, as so frequently is done, one looks only at the present and ignores the historical trend, then herbaria appear to be growing and spreading more rapidly than ever, which actually is true in some parts of the world where the last five or ten years have chalked up a larger roster of foundings than the first 200–350 years (cf. Tables 5–12 and next section). Worldwide, about 300 years passed before the first 100 herbaria were formed, but the last 100 of the 933 herbaria have been founded in just over 17 years (Table 14)! During the most recent 5-year period for which statistics are available, 13 herbaria have been founded—as

many as were founded during the entire first 200 years (to 1750). Obviously the herbarium is far from being a dead institution. Yet it also must be noted that the annual rate of foundings has decreased from 6.6 herbaria/year during the first 63 years of this century to 4.2 during the last 10 years and 2.6 during the last 5 years of this period.

Geography of Herbaria

The world's herbarium resources are analyzed by continent or region in Tables 1 and 2 and by country (top 22 countries only) in Tables 3 and 4.

Today's 933 herbaria are located in 104 countries, averaging about 9 herbaria, or 1 percent of the total, per country. In fact, however, only 22 countries have the average 9 herbaria or more. Of the 104 countries, 37 have only one herbarium, 77 have five or less, and 95 have twenty-five or less. The top five countries and their numbers of herbaria are: USA (244), Great Britain (50), Canada (48),[8] USSR (43), and France (42). Only the first place of the United States is clearly established, and this is true whether the criterion is number of herbaria, number of specimens, or number of staff. The ranks of the other countries change when the latter two criteria are used; Canada drops to 13th place when ranked by number of specimens but only to 5th place by number of staff, while France places 2nd and Great Britain 3rd by both of these standards. The rank of the USSR cannot be determined confidently with the available statistics in *I.H.* because of the relatively large number of herbaria not reporting full data; quite possibly the USSR ranks next to the USA. Likewise, in reality China might rank among the top five, but the highly incomplete data place her out of the running.

The 10 leading countries have 63 percent of the world's herbaria; none of the other 94 countries has as many as 20 herbaria. In the United States, every state has at least one herbarium, and

[8] On behalf of the Systematics and Phytogeography Section of the Canadian Botanical Association, W. K. W. Baldwin of the National Herbarium of Canada (CAN), Ottawa, has been making a special study of Canadian herbaria during the past few years in an effort to provide better data for the forthcoming 6th edition of *Index Herbariorum*. His progress reports, which have been distributed but not published, reveal that there are more than 60 herbaria in Canada at the present time. I have not attempted to incorporate his incomplete results here.

California leads with 27. Half of the USA's 244 herbaria are found in California and six other states: Texas, 22; Michigan, 19; Massachusetts, 17; Pennsylvania, 14; New York, 12; and Ohio, 10. If the continents of Europe and North America are treated broadly, as follows, then each is seen to have about a third of the world's herbaria: Europe + British Isles = 327 herbaria; North America (including Mexico and Central America) + West Indies = 315 herbaria. Asia places a distant third place with 114 herbaria or, including the Australasian-Pacific Island region, with 158 herbaria.

The 933 herbaria of the world are found in 669 cities, averaging 1.4/city. Thus, inefficient and wasteful as it may be to maintain two or more facilities and collections within the same city, such duplication has been common practice. Historical precedent or petty institutional sovereignty and politics too often seem to outweigh the scientific logic and simple economics of consolidation. Ironically, moreover, it seems to be a universal fiscal principle of bureaucracies, at least governmental ones, that two small units often can command greater total support than one large, consolidated unit.

As mentioned earlier, the herbarium was an almost exclusively European institution for more than 200 years. Then slowly it was transplanted to foreign soil by European naturalist explorers turned settlers, and over the years the geographic focus of active herbarium-founding has tended to shift more or less in phase with the shifting thrust of European and, eventually, North American exploration and colonization. An indigenous tradition did not take hold in North America until well into the 19th century nor in Asia and Australasia until as late as the early 20th century in some parts. Only in quite recent years has the herbarium become truly indigenous in Africa and South America.

This shifting focus of activity can be documented statistically. Table 14 compares the geographical distribution of the first 100 herbaria founded with the geographical distribution of the last 100 founded, i.e., counting back from 1963, the most recent year for which *I.H.* gives data. The figures, which can be read directly as percentages, speak for themselves.

During the recent 25-year period from 1939 to 1963, in-

clusive, 150 herbaria were founded, and North America (including Mexico but excluding Central America and the West Indies) led with 42, followed by Africa with 28, Europe with 26, South America with 21, and Asia with 19. If only the last 10 years of this period are considered, then Africa noses out North America by one herbarium (9:8). Herbarium-founding has tapered off greatly in Europe, where on the continent not a single new herbarium was formed during one recent 5-year period (1954–59), and several countries apparently have not founded a new herbarium this century; nevertheless, it is quite remarkable that any herbaria at all are still being started here, as at Aarhus, Denmark, in 1963. This speaks well for the continuing vitality of descriptive botany in Europe. In North America, the focus of active herbarium-founding is shifting from the United States to Canada. A surge of herbarium-building in Mexico comparable to that taking place recently in Canada has yet to begin.

The countries of Africa and South America probably never will experience a herbarium boom to equal that experienced in Europe or North America. For one thing, Europeans and North Americans continue to do a large portion of the tropical collecting and research and, therefore, to carry most of the spoils of exploration back to their home institutions. Furthermore, the present rapid evolution of biology away from the descriptive stages, the accelerating pace of the race to conclude the botanical exploration of the earth, and the growing worldwide concern about overpopulation and its destruction of our natural environment—all seem to be foreclosing on any new herbarium boom of the scale witnessed in north temperate regions by the last 100 years. The coming of rapid, easy means of transportation during the present century has greatly stimulated and facilitated worldwide exploration. Seemingly, however, modern means of travel have served mainly to aggrandize the long-established herbaria and have stifled rather than stimulated the creation of new herbaria, because in a jet age the remotest parts of the world are but a research grant away from any would-be collector's home base. At the same time, representing a growing, unpredictable counterforce, which in many countries (e.g., in Africa) already has curbed explorations by foreigners

and spurred much new, indigenous herbarium-building, is the rising tide of nationalism that generates demands for national science and scientific institutions.

Obviously, many factors may govern the development of herbaria within a country. Size of home territorial area may be least among them, witness Great Britain and the countries of Europe. By contrast, the huge size and floristic diversity of the Soviet Union have been major factors in keeping most Russian botanists at home through the years, while at the same time this size and diversity have enabled them to amass large and rich collections (Shetler 1967). The impact of the land-grant legislation in the United States, discussed above, demonstrates the obvious point that the development of herbaria within a country is closely dependent on the general level of educational, scientific, and economic development of the country as a whole. A country that does not have mature scientific traditions and institutions also will not have well-developed herbaria nor the scientific and educational foundations to support them. Every country goes through a predictable golden age of its own with respect to the formation of indigenous herbaria, and this curve is a minor reflection of the country's curve of overall development. Political considerations, especially as they have governed the national and international movements of botanical collectors and their specimens, have often limited the character and scale of herbarium-building in a country at least for a time. The prime modern example of this is to be found in China.

Organizational Status of Herbaria

About 59 percent of the world's herbaria are university-affiliated, 34 percent government-affiliated, and 7 percent independent. This classification does not indicate necessarily the source of funds. In the United States, for instance, virtually no public herbarium operates entirely on private funds today; county, state, or federal funds provide at least some support. The dominance of university herbaria speaks for the importance traditionally accorded to plant collections in academic botancial research and education. The rapid increase of herbaria in North America during the past 100 years has been due in large part to the rapid increase of state and provincial univer-

sities, many of which have botany departments or botanical gardens with associated herbaria. The influence of the land-grant acts in the United States has already been mentioned, and to this should be added the exemplary, early influence of prestigious schools and teachers. Concerning the development of the herbarium as an integral element of university botany, it would be hard to overestimate the profound influence of men like Asa Gray (1810–88) and Liberty Hyde Bailey (1858–1954) or of the institutions they served. Since the time of Asa Gray, some of America's foremost academic botanists, indeed scientists, have been herbarium scholars who have made the university herbarium a primary locus of research and teaching. In the United States today, Jones and Meadows (1948) point out, ". . . almost without exception no first-class university has a second-class herbarium . . . ." "Likewise," they comment, "there seems to be a very close connection between development and utilization of the herbarium and the vigor and prestige of a botanical department." Chairmen of university botanical departments would do well to savor these observations. Surely the same kinds of comments about the historic role of academic herbaria could be made for many countries.

When only the 17 largest herbaria, with 2 million or more specimens each, are considered, then 53 percent are seen to be government-affiliated, 35 percent university-affiliated, and 12 percent independent. The relatively higher percentage of government-affiliated herbaria in this group than among herbaria at large reflects the fact that government herbaria are often among the earliest to be founded in a country and they tend to receive greater and more stable support through the years than other herbaria, enabling them to grow larger than others.

Types of Herbaria

Historically, it has not been customary to develop cryptogamic and phanerogamic herbaria as separate institutions, although many general herbaria have been organized into different laboratories or divisions for different groups of plants. According to available data in *I.H.*, only about 6 percent of the world's 933 herbaria are strictly cryptogamic herbaria. Among

these, however, are some world-famous institutions, including three with a half-million or more specimens: *Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle*, Paris (PC, 1.2 million); Farlow Herbarium of Cryptogamic Botany, Harvard University, Cambridge, Massachusetts (FH, 1 million); and National Fungus Collection, U. S. Department of Agriculture, Beltsville, Maryland (BPI, 675,000, including Smithsonian fungus collections). One must hasten to add that there are other large cryptogamic collections (e.g., at Komarov Botanical Institute, Leningrad, 1 million specimens) that are not organized as independent herbaria. In reporting data for future editions of Index Herbariorum, institutions should attempt to distinguish more carefully, the kinds of collections they hold so that a better picture of the world's resources by plant groups can be gained.

Size of Collections

With 724 (78 percent) of the 933 herbaria reporting size of collection, specimens total about 148 million. If one were to assume that the same average per herbarium (ca. 205,000 specimens) holds for the 22 percent not reporting size of collection, then the extrapolated total for the 933 herbaria would be 190 million specimens. Furthermore, if to the 190 million were added specimens hidden away in national parks and the small herbaria of municipal, county, and state or provincial museums, schools, and parks, then surely the world total for institutional herbaria would reach 200–225 million and possibly as high as 250 million specimens.

Over 131 million, almost 90 percent, of the 148 million specimens are held by the 22 countries with 9 or more herbaria each (Table 3). With few exceptions the countries having the most herbaria also have the most specimens, although the ranking is different. Some of the European countries that have had herbaria for a very long time rank comparatively much higher in number of specimens than in number of herbaria (e.g., Czechoslovakia). About 78 million of the 148 million specimens are concentrated in Europe. This is more than double North America's 36 million specimens, and European herbaria also average more than twice as many specimens per herbarium as North American herbaria (Table 1).

As a country, the United States of America, with 34 million based on 86 percent of its herbaria reporting size of collection, leads the world in total number of specimens. It has about a quarter of the world's specimens (23 percent) as well as herbaria (26 percent) (Table 3). Apparently it is the only country that has more than 20 million specimens. The nearest competitor, France, has less than half as many specimens (nearly 15 million); however, this figure is based on only 57 percent of the herbaria reporting size of collection, so that the real total could be well over 20 million. Of the 95 countries for which specimen totals can be compiled from *I.H.*, 48 report 100,000 or less, and only 3, including the USA, report more than 10 million. Over a third of the countries have totals between 25,000 and 250,000 specimens. The average for the 95 countries is just under 1.6 million/country, although only 10 percent of the countries have totals that fall into the range of the average, i.e., 1–2 million.

Compared by average size of herbarium, the USA, with its 160,142 specimens/herbarium, falls far behind other countries. The top four countries, their herbaria being the only ones to average more than a half-million specimens each, are: Switzerland (994,286/herbarium), Sweden (965,875/herbarium), Czechoslovakia (650,000/herbarium), and France (609,067/herbarium). These are countries with long herbarium traditions where the existing network of herbaria has been stabilized for some time, and few if any new herbaria are still being formed.

Forty-five countries have at least one herbarium each with as many as 100,000 specimens; 25 countries have at least one herbarium with 500,000 or more specimens; 19 countries have at least one herbarium with 1 million or more specimens; and 11 countries can claim at least one herbarium of 2 million or more specimens. Only 6 countries of the world—France, Great Britain, Italy, Switzerland, USA, USSR—can boast at least one herbarium of 3 million or more specimens (Table 13).

The statistics in Table 15, based on the 724 herbaria reporting size of collection in *I.H.*, give a good indication of the size-class distribution of the world's herbaria. As expected, most herbaria are relatively small, and few are really large. It ap-

pears that almost half of the world's herbaria have no more than 25,000 specimens and that almost three-quarters have no more than 100,000 specimens; about 10 percent have 250,000 or more, and only about 5 percent have a million or more specimens.

The 39 "big league" herbaria reporting 1 million or more specimens are listed with appropriate statistics in Table 13 in order of decreasing size. This list includes 9 herbaria of the United States, the country with the largest number of herbaria that have 1 million or more specimens. There are 17 herbaria with 2 million or more specimens each, and together they have 57 million specimens, more than a third of the total 148 million. The 10 herbaria with 3 million or more specimens together have a total of 41 million specimens. Thus it would appear that 25–30 percent of the world's herbarium specimens are concentrated in 1–2 percent of the world's herbaria, namely, the world's very largest herbaria. It is certain that at least some of the 209 herbaria for which collection size is not given in *I.H.* (e.g., herbarium of British Museum in London) belong in Table 13, but there is no way to take these into account. One must assume that in relative terms this table gives an accurate picture of the world's largest herbaria and their holdings and staff.

The largest herbarium in the world unquestionably is the herbarium of the Royal Botanic Gardens at Kew near London, England, which in 1963 could boast a staggering 6.5 million specimens. Second place is open to question, however. On the basis of the data in Table 13, the clear choice is the *Muséum National d'Histoire Naturelle* in Paris *if*, ignoring the administrative separation into two herbaria (P and PC), the 5 million phanerogamic and 1.2 million cryptogamic specimens are added together to make a total of 6.2 million. On the basis of the phanerogamic herbarium alone, the Paris museum may stand in third place behind the Komarov Botanical Institute in Leningrad, where the phanerogamic and cryptogamic collections, which are administered as one herbarium, total between 5 or 6 million specimens. The Leningrad herbarium has about 1 million cryptogamic specimens, but there is some confusion concerning the number of phanerogamic specimens, whether 4 or 5 million (*see* footnote, Table 13). Inasmuch as cryptogams

are included in the Kew and Leningrad totals, it seems only fair that Paris be compared on the same basis. The herbarium of the British Museum is not included in Table 13, but already in 1951 it was estimated by Lawrence (p. 231) to have 4 million specimens. As of 1963, therefore, it might have placed second or third in size among the world's herbaria. One of the world's largest herbaria (ca. 4 million specimens) until World War II was located in Berlin, but it was destroyed in the war.

The largest herbaria of the New World are found in the United States, and it is a matter of interpretation which places first, second, and third. According to Table 13, the herbarium of the New York Botanical Garden and the U. S. National Herbarium at the Smithsonian Institution, Washington, D. C., were, with 3 million specimens each, tied for first place in 1963. Frequently, however, the six herbaria of Harvard University (A, AMES, ECON, FH, GH, NEBC), Cambridge, Massachusetts, are combined when size comparisons are made, and if this is done Harvard takes the lead, as of 1963, with 3,540,150 specimens. But if this is done for the Harvard herbaria then the National Fungus Collection at Beltsville, Maryland (just outside Washington, D. C.), which includes the Smithsonian's mycological specimens, should be considered part of the U. S. National Herbarium, and the combined total, as of 1963, was 3,675,000 specimens. If, furthermore, the other herbaria of the Washington area (LCU, MARY, NA, USFS) are added to this figure, then the grand total is 4,335,000 specimens. By the same token, the 294,000 specimens of the Brooklyn Botanic Garden should be added to the specimens of the New York Botanical Garden to give a total of 3,294,000 for greater New York City. In terms of specimens available within the city, therefore, Washington is first, followed by Cambridge and then New York.

The smallest herbarium on record is located in Siena, Italy, and had 492 specimens in 1963. It happens also to be the 9th oldest herbarium in the world, being founded in 1691. This is the only herbarium reporting less than 500 specimens, although three others (HNT, SEY, SPH) report just 500.

The general rate of collection growth is difficult if not impossible to determine even for a given time period. Clearly the relative growth rate has been slowing down through the years

as the bulk of the world's collections has been increasing steadily. Absolute growth, i.e., in terms of actual number of specimens coming into herbaria, has increased greatly over the past 100 years or more as the number of herbaria and botanical collectors has increased, but there is definite indication that even absolute growth is on the decline now. Compared to the total of about 124 million specimens registered in the 1959 edition of *I.H.*, the total in the 1964 edition is about 24 million higher. The 13 herbaria founded in the period 1959–63, inclusive, report a total of only 145,000 specimens; obviously, these herbaria do not account for a significant portion of the 24-million increase. Between editions of *I.H.* the U. S. National Herbarium increased by about 300,000 specimens or 11 percent, as computed on the 1958 base of 2.7 million. If one assumes that herbaria in general increased their holdings by about 10 percent during the 5-year period (i.e., 2 percent/year), then 12–13 million of the 24 million specimens would represent the growth of collections in previously registered herbaria. This is about 2.5 million specimens/year, a not unlikely figure for the whole world. The other 11–12 million of the 24-million-specimen increment probably are contributed by the more than 150 herbaria reporting for the first time in the 1964 edition of *I.H.* even though they were founded before 1959 and should have been reporting in 1959 or before. Their specimen total does not represent new growth, except perhaps for about 10 percent of it.

Today, growth relative to the size of existing collections could be averaging as low as 1 percent per year among herbaria in general, meaning an annual worldwide increment to herbaria of 1.5–2.0 million specimens. Probably the rate lies closer to 2 percent per year, however, because some herbaria are growing several times this rate (e.g., Michigan State University Herbarium, 5–10 percent/year). During the last five years Canadian herbaria have been growing at an average rate of more than 6 percent/year (W. K. W. Baldwin correspondence, 1969).

Manpower

Size of professional staff ranges from 1 to 46, averaging about 4, persons per herbarium and totals 3,158 persons for the 794 herbaria (85 percent of 933) that list one or more staff mem-

bers. The frequency distribution of the 794 herbaria by size of staff is as follows:

1 staff member	199 herbaria	25 percent
1 or 2 members	395	50
5 or less members	640	81
10 or less members	742	93
11–46 members	52	7

Only 11 herbaria, listed in Table 16, report 20 or more staff members (as of 1963). About 75 persons (2.4 percent of 3,158) are listed for two jobs in *I.H.*, so that the total number of different individuals is under 3,100 and the average is about 3.9/herbarium. (Double employment cannot be distinguished easily from accidental duplication; *see* "Source of Statistics.") Extrapolating with this average, one concludes that the full 933 herbaria are in the care of more than 3,600 individual curators. If 2–3 percent of the 3,600 serve in two capacities, then the total number of professional positions occupied is over 3,700.

Distribution of herbarium staff by continent or region is shown in Table 2. The largest concentration is in Europe (36 percent). North America (25 percent) takes second place, followed by South America (11 percent). If the data for Asian herbaria were more complete, this continent probably would place third. There are 96 countries out of the total 104 for which the staff members of at least one herbarium are listed in *I.H.* Of the 96 countries, 37 report 5 or fewer staff members, while 73 report 25 or less; 9 countries report more than 100 staff members. Only two countries, the United States with 667 and France with 220, report more than 200 staff members. The USA has over 21 percent of the world's herbarium force, based on these statistics, and France has 7 percent. (By comparison, the USA has 26 percent of the world's herbaria and 23 percent of the specimens, while France has about 5 percent and 10 percent, respectively.) The 21 countries that lead in total number of staff are among the 22 countries that lead in total number of herbaria, listed in Tables 3 and 4, although the ranking differs, as can be seen in Table 4. Finland, included in the tables, has 30 curators and ranks 23rd in staff size, whereas Belgium, not included in the tables, has 31 curators and ranks 22nd in staff

size. Except for Belgium, therefore, Tables 3 and 4 include all countries with 30 or more staff members as of 1963.

Few if any of the world's herbaria would claim to be staffed adequately, and almost every curator would consider himself overworked. Yet there are no absolute standards by which one may judge the adequacy of professional (or technical and clerical) staffing. Instinctively, one can say that any herbarium with less than one full-time curator is understaffed or that any person holding down two curatorial positions, as about 2 percent of the world's curators apparently do, is overworked. Saying this hardly sheds light on the general question. There are, however, two useful ratios that measure objectively the relative adequacy of staffing of a herbarium or country: (1) average number of specimens per curator, and (2) average number of curators per herbarium. Thus herbaria or countries can be compared with each other or with the world as a whole by their specimen:curator ratios. Likewise, countries can be compared with each other or with continents or the world as a whole by their curator:herbarium ratios. To be sure, these ratios may bear little relationship to the level of activity in particular cases, especially where a significant fraction of the curators identified with an institution or country are not actually engaged in herbarium research and curation; nevertheless, these ratios are the only objective measures of staffing we have. Other factors being equal, an above-average curator:herbarium ratio reflects a favorable staffing situation, while an above-average specimen:curator ratio, i.e., more than the average number of specimens per curator, reflects an unfavorable staffing situation.

Average curator:herbarium and specimen:curator ratios are given in Table 2 for continents or regions and Table 4 for the 22 countries with the most herbaria. As already mentioned, there is an average of 4 curators/herbarium among the 794 herbaria reporting staff. South America, as a continent, leads the world with an average of 5.5 curators/herbarium, followed by Europe with 5.0/herbarium. North America trails with 3.0/herbarium. Among the 22 top countries, the Netherlands leads with 10.9 curators/herbarium, while the United States trails with 3.0/herbarium. The favorable South American ratio appears to reflect aggressive herbarium growth on this continent

and also a liberal concept of reckoning staff (*see* below). The relatively high European ratio seems to be a more authentic representation of the true situation.

The average number of specimens/curator among the 794 herbaria is about 47,000. The herbaria of the British Isles lead the world with an average of almost 95,000 specimens/curator, while continetal European herbaria follow with 78,000/curator. The lowest ratio is to be found in the West Indies, where each man curates an average of about 6,000 specimens. Ignoring Madagascar, where there are only 3 herbaria, the second lowest average for a large region, about 10,000 specimens/man, is found in South America. By country, Switzerland leads with about 170,000 specimens/man, followed by Czechoslovakia (134,000/man) and the USSR (87,000/man). The high ratio of specimens to curators in Europe and the British Isles reflects the existence here of old, very large herbaria. In general, the European countries rank above average both in curators to herbaria and in specimens to curators.

In North America, the United States, with about 50,000 specimens/man, ranks near the world average, while Canada, with 19,000/man, and Mexico and Central America together, with about 10,000/man, rank well below the world average. On the basis of curators/herbarium, the United States, Canada, and Mexico and Central America all rank below the world average at 3.0, 3.2, and 3.3, respectively. Among North American herbaria, therefore, those of the USA are the least well staffed.

As a group, the world's largest herbaria appear to be seriously understaffed. The 17 herbaria with 2 million or more specimens (Table 13) have among them 38 percent of the world's 148 million specimens but only 8 percent of the world's 3,158 curators. The 11 herbaria with the largest professional staffs (20 or more members each) have 19 percent of the world's herbarium specimens but only 11 percent of the world's curators. If one computes ideal professional staff size for these 11 herbaria on the basis of the worldwide average of about 47,000 specimens/curator, the results, given in Table 16, are very interesting. By this standard some herbaria prove, as expected, to be grossly understaffed, but others, surprisingly, seem to be even more grossly "overstaffed," if indeed one may

speak of any herbarium being overstaffed. Certainly the staff figures of individual herbaria must be regarded with some skepticism and be interpreted in the most cautious, relative terms, because of the lack of uniformity among institutions in reckoning who is a professional staff member. Thus, for example, the herbaria at Montpellier, São Paulo, and Buenos Aires report essentially all faculties of their respective botanical institutes instead of just those persons who actually might be considered to belong to the professional curatorial staff. Probably Kew ranks first in number of authentic herbarium staff, which means that the largest staff in 1963 totalled about 40 professional persons. Despite individual discrepancies, it is noteworthy that the 11 herbaria as a group have only about half (56 percent) of the professional staff that they should have to meet average conditions.

It may seem unfair to measure the adequacy of staffing in large and small herbaria by the same specimen:curator ratio, because the small herbarium must have a relatively larger staff for its size than the large herbarium. The maintenance of any herbarium, regardless of its size, entails certain basic curatorial tasks and functions, and minimum staff size, obviously, is one person. The larger the herbarium, the more efficient it becomes in terms of number of specimens that a curator can manage. Tending to counteract this gain in efficiency, however, is the greater workload of the large herbarium, which gains in service responsibilities to the scientist and layman as it gains in size and thereby general usefulness and visibility. It is problematical, therefore, whether the large herbarium should be measured by a different specimen:curator yardstick than the small herbarium.

For purposes of discussion I have assumed until now that the more than 3,000 persons listed in *I.H.* are all professional curators, because there has been no other firm basis on which to analyze professional manpower in the world's herbaria. In fact, as already indicated ("Source of Statistics"), this is not a safe assumption. While the *I.H.* figures may give a roughly accurate picture of the number and deployment of the world's *herbarium-affiliated* botanists, although even this can be disputed, given the kind of peripheral scientific staff that one

finds listed for some herbaria, quite clearly the more than 3,000 persons who are listed for the 794 herbaria reporting staff do not all engage actively in curatorial work or work that can be construed as contributing directly to the building and maintenance of these herbaria. Many are associated researchers or administrators who have few if any routine curatorial responsibilities. This is not to denigrate the essential, if sometimes indirect or intangible, contribution of such personnel to the well-being of the collections and the scientific life of the herbarium. Yet it should be recognized that probably no more than 1,500 to 2,000 of the approximately 3,000 staff are really curators. The extrapolated figure for all 933 herbaria would be 1,800–2,400 curators.

Finally, professional staff represent only part of the world's herbarium manpower. To their number must be added the technical and clerical supporting staff. At the U. S. National Herbarium, the ratio of supporting to professional staff has tended in recent years to remain at about 1:1. This certainly is neither the best nor the worst ratio among the world's herbaria. If for comparative purposes we may assume that it is an average ratio, then all figures given for professional staff should be doubled to project total herbarium manpower. It seems likely that upwards of 7,500 persons, working in one capacity or another, are employed in the 933 herbaria treated in *I.H.* Considering that these 933 herbaria could represent a fifth or less of the world's public institutional herbaria (*see* "Source of Statistics"), one must conclude that at the least there must be well over 10,000 persons employed in herbarium-related work (profession, technical, or clerical) and at the most there could be upwards of 35,000 or even more persons manning the world's herbaria. Probably the truth lies somewhere between these extremes.

The Modern Predicament

On 8 May 1964, a symposium was convened at Michigan State University on the theme "The Herbarium in the Modern University" to dedicate new quarters for the university's herbarium, founded in 1863. (These quarters, in a renovated old building, had been occupied since the summer of 1963.) The event was a resounding success. On short notice, 160 persons, rep-

resenting 49 institutions, attended. Thus the taxonomic community responded to this herbarium pulse-taking with a vitality that few would have predicted. Later, when the symposium was published, John H. Beaman, curator of vascular plants and organizer of the symposium, could write (Beaman, Rollins, and Smith 1965, p. 113), "The attention which the program attracted was an effective demonstration of the high level of current interest in the herbarium as a resource for taxonomic teaching, research, and service." As local administrators said convincingly what their subordinate curators wanted to hear and as the speakers optimistically tallied up several hundred years of achievements, pointing to unprecedented growth and activity at present, those attending found themselves engulfed in a euphoria of hope and prosperity. The National Science Foundation, indispensable patron of American science, was duly represented by the director of the Systematic Biology Program, who then was Walter H. Hodge, himself a botanist. Dr. Hodge presided and, while acknowledging such chronic and worrisome problems as inadequate public understanding, financing, staffing, and facilities, was able to conclude his summation on an upbeat with the welcome appraisal that the herbarium today is "progressing rather than regressing."

During the first week of September 1968, just *five* years after the renovated building had been occupied, a demolition crane moved into position, and its great iron ball began swinging. In exactly one-half day, less time than it took for the dedication, the building that was opened with fanfare and great hopes in May 1964 was reduced to a pile of rubble! The pendulum of progress had swung, pulverizing a modern university herbarium "to make way," in the words of *Fortune* magazine writer Duncan Norton-Taylor (1967), "for the driveway to the new Administration Building." For the second time in six years the whole collection of plants had to be moved, at last to truly new quarters, but again at great cost in effort and lost research time.

To be sure, I have not told the whole truth. The curators knew when they first occupied it that this newly renovated building could serve only as an interim home for the herbarium during the indefinite period between vacating the original quarters and moving into some permanent quarters yet to be

planned and built. They did not know how very temporary the interim quarters were to be. Now the herbarium is located in the recently built Plant Biology Laboratories, where it occupies twice as much floor space as it had occupied in its original quarters. So well off is the herbarium, in fact, that for the first time its fortunes are even cause for a certain amount of envy at the university.

But is this momentary good fortune illusory? The present quarters also are a temporary refuge—hopefully for no more than 10 years. A truly permanent home is to be provided some day in a new museum building not yet begun. Furthermore, the two curators who are mainly responsible for developing and maintaining the herbarium (Beaman and H. A. Imshaug, curator of cryptogams)[9] must run a full research and teaching program for graduate and undergraduate students while also trying to manage a collection of more than 200,000 specimens, to which are accessioned about 10,000 specimens/year. This is 100,000 specimens/man, twice the national average, and at this rate of accessioning the herbarium should be gaining a new professional staff member every 4–5 years.

The Michigan State University Herbarium certainly is not impoverished; neither are the responsible university administrators myopic. Quite to the contrary, it is a university herbarium of unusual vitality with indefatigable curators and with administrators who thus far have demonstrated uncommon understanding and foresight. Yet this is precisely the point: the university herbarium today (indeed the herbarium in general) seems at best to lead a fragile existence, and no amount of activity and leadership can cover up the ever-present stresses and strains that threaten this existence constantly. As Beaman (1965, p. 113) writes, "The herbarium is the oldest, most essential, most expensive, and most difficult to develop of all facilities for the study of systematic botany. Consequently, the occupancy of new quarters by a herbarium, however modest, is an event of note." Wrapped up in his words is the paradox of the herbarium, especially in the university setting: es-

[9] This is a good case in point of how the number of staff listed in *Index Herbariorum* may bear little relationship to the number actually responsible for most or all of the curating. Of the 10 persons listed, only 2 (Beaman and Imshaug) were, as of 1963, carrying much of the burden of curation.

sential but too expensive to be developed, accommodated, and maintained adequately. The elements of crisis or collapse, namely, collections that continually are outgrowing facilities, staff, and other resources and a science that constantly is changing, are always present. The slightest erosion, therefore, of the historic scientific and intellectual foundations of the herbarium can precipitate instant crisis, and this is what we seem to be witnessing with increasing frequency as classical botany comes under the molecular gun. Confused by challenges of the scientific worth of the herbarium, administrators may need little persuasion to decide that the herbarium is an expensive, latter-day white elephant, which in terms of resources demanded is a facility that drains more than it adds to a modern science program.

The Michigan State University symposium dealt only with university herbaria. In the international commerce of taxonomic research, however, the large nonuniversity herbaria are crucial institutions. What then is the state of affairs in such large herbaria as the U. S. National Herbarium at the Smithsonian Institution? Today, with 3 million specimens, it is one of the ten largest herbaria in the world and one of the three largest in the New World. The bulk of these specimens has been accumulated during the present century. As Stern (1966, p. 8) has said, "it is a safe assumption . . . that there is no serious research of any scope which can be executed in systematic botany in the United States without some recourse to the plant specimens of the U. S. National Herbarium." One might amend this statement by saying that any taxonomist in the world wishing to conduct serious research on temperate North American plants surely will need to take recourse to collections of the U. S. National Herbarium, among others in the United States, at some time during his study.

By some standards the U. S. National Herbarium has often seemed the rich uncle among herbaria in the United States. As the largest of the few American herbaria with direct access to appropriated federal funds, it appears to occupy a favored position.[10] During the past few years the Smithsonian's Depart-

[10] Direct appropriation is not the only form of federal support in the USA. Since the National Science Foundation was formed, large, though inadequate, amounts of

ment of Botany has indeed experienced unprecedented growth and prosperity. In 1965, the department and its herbarium were able finally to occupy new quarters, a move culminating years of dreams. A year later hopes were raised (Stern 1966) for the acquisition of new metal cases to replace the more than 2,200 archaic, inefficient wooden cases, which are not insect-proof. For the first time in history the National Herbarium seemed to be heading toward a fully modern facility, even if, as at Michigan State University, the quarters were hardly designed for a herbarium (e.g. a plant-drying facility was not included in the plans!). The staff of full-time professional botanists had grown to an all-time high of 16.

Already this hard-won improved status has begun to erode, as the inexorable growth of the collections continues without a concomitant increase in space and staff. At present, in fact, the department has a smaller full-time professional staff (13)[11] and less available office space (1.2 rooms/man instead of the original 2/man), which is occupied to the point of crowding, than when it moved in 1965. Although the specimens per curator ratio is only one index of staffing adequacy, yet it is significant that on this basis the department should have about five times its present number of full-time curators, to say nothing of supporting staff (Table 16), just to meet average conditions. The professional botanists continue to do much of the routine curatorial work because of the perennially unfavorable ratio of curatorial assistants to curators which temporarily may reach as high as 1:2 but usually is 1:3–4. Owing largely to understaffing, some 200,000 specimens, as many as the Michigan State University Herbarium comprises altogether, must remain in dead storage, freezing nearly a fourth of the available storage cases. Specimen storage space probably will reach saturation conditions in the herbarium in less than 10 years, by which time

federal support have been granted to many American herbaria for research and facilities. This fact sometimes is overlooked, and the myth arises that the National Herbarium is the only federally supported herbarium in the USA.

[11] This number, unlike the figure of 21 in *I.H.*, excludes resident emeritus curators, honorary research associates, collaborators, postdoctoral associates, and long-term visiting scholars who usually swell the professional ranks by 10–15 persons a year but do not have obligatory curatorial responsibilities, although frequently they contribute much help. It includes, however, several full-time staff botanists of the department who have little or no responsibility for the collections.

virtually all working space in the herbarium will be occupied by cases. Some parts of the herbarium already are so overcrowded that specimen filing is difficult if not impossible. The effort to replace the wooden cases in toto collapsed, and as of today only a relatively few have been replaced.

Meanwhile, the National Herbarium continues to be very active, and the workload only increases. Over the 10-year period from 1958 to 1967, about 700,000 incoming specimens—41,000 to 120,000/year and averaging 70,000/year—have been processed as gifts, exchanges, or specimens collected by or for the herbarium's botanists. During the same period, 20,000 duplicate specimens/year of the 70,000 have been turned around and sent out on exchange, while 37,000 specimens/year have been mounted for addition to the herbarium, leaving about 13,000/year that of necessity have gone into dead storage. Thus some 50,000 specimens have been retained, which means that every year the herbarium should be adding at least one new professional botanist and commensurate supporting personnel just to cope with the inflow and processing of material. Incoming exchange has averaged 25,000 specimens/year, leaving an accumulating exchange deficit of 5,000/year. Duplicate exchange usually is a deficit operation for the large herbarium, which by virtue of its size and importance must cooperate in many more exchanges than the small or medium-sized herbarium. To attempt to balance the books is futile: the more specimens sent out, the more that come back, and the total inflow always seems to outstrip the outflow. If, therefore, the National Herbarium suddenly were able to find the extra 5,000 exchange duplicates each year to meet the deficit, any balance would only be momentary, because the cooperating institutions would be stimulated quickly to send us still more specimens, perhaps doubling or tripling our annual deficit. Loans for research also have increased steadily from the 16,700 specimens borrowed from the National Herbarium in 1961 to the 41,500 sent out in 1967, averaging about 25,000/year over the 1958–67 period. Finally, requests for identifications keep rising, and nearly 180,000 identifications were made over these 10 years. In short, the National Herbarium, like any large herbarium, is big business.

To a greater or lesser extent, nearly every herbarium in the

world is faced with the problems, dare I say predicament, of the Michigan State University Herbarium or the U. S. National Herbarium (e.g., *see* Rollins *et al.* 1967–68). Regardless of the category of transaction, there seems to be no way to stem the rising workload and service demand. At the same time the intellectual foundations of the herbarium seem to be crumbling within science today with an ever-increasing tempo making it harder and harder for herbaria to justify and secure the kind of support needed. Given the intensifying predicament, serious crisis cannot be far away. It is regrettable, therefore, that inner-circle conclaves like the 1964 symposium do not, for all their timely challenges and encouragements, challenge any of the sacred cows or age-old premises of the herbarium mentality. The handwriting, it would seem, is on the wall, and the message should cause concern if not alarm. If through rosy glasses a move to new quarters means growth and prosperity, plain sight might reveal that it really means harassment and retrenchment, with the collections being chased from one temporary asylum to another, never gaining a permanent berth in their own right and always being put out of mind administratively by another wishful promise. It is becoming critical, surely, for curators to interpret the signals correctly.

Clearly it is time to establish new relevancies and strategies for the herbarium. Considering that herbarium growth potentially is limitless, it is not surprising that the kind of statistics cited above give administrators uneasy feelings. Unless there are new objectives with rational limits and strategies that go beyond merely asking for bigger and better facilities, the current predicament is likely to deepen into an insoluble crisis, locally and generally.

Economics Of Herbaria

Investments and Costs

To my knowledge, a thorough analysis of capital investment and cost of operation has never been made for herbaria. This important task will require lengthy study to produce complete and reliable results, and herbaria, at least on a national basis, should attempt it as a basis for seeking more federal support. It

is, in fact, an almost impossible task, given the great variation of facilities and expenditures from one herbarium to another, not to mention the problem of currency differences between countries. My cost analysis, which is rough and sketchy, is based on extrapolation from the situations at the Michigan State University Herbarium and especially at the Smithsonian's U. S. National Herbarium. I may be presumptuous to attempt this, but surely some hints of costs are needed.

The cost of herbarium space and equipment is approximately $50/sq. ft. at Michigan State University and approximately $100/sq. ft. at the Smithsonian Institution, where, however, the density of stored specimens per square foot is about double that of Michigan State. Consequently, the static cost of housing specimens is about $2/specimen in both cases. Projected on a national scale at this rate, the capital investment for herbaria in the United States is at least $70 million today, and the worldwide investment is nearly a third of a billion dollars. Even if the average cost were only $1/specimen the worldwide investment would be $150 million.

In any herbarium, the specimen storage cases are the main item of equipment. The U. S. National Herbarium housed its 3 million specimens as of 1963 in about 2,200 cases.[12] Figured at $100/case, which was the minimum cost of replacement at that time, these 2,200 cases represented an investment of almost a quarter of a million dollars. Using the National Herbarium's average of about 1,350 specimens/case, one can extrapolate, and on this basis the USA had some 25,000 cases as of 1963, while there were about 110,000 in the world. (Phanerogamic specimens average only about 1,000/case, whereas some of the cryptogamic groups average more than 1,350/case.) At $100/case or its equivalent in other currencies, these totals represent investments of about $2.5 million in the USA and about $11 million in the world.

Overall operating expenditures vary from year to year and herbarium to herbarium. One of the problems of cost estimation, given the budget of a herbarium, is to separate research costs from curatorial and herbarium-service costs. Thus, for example, the Smithsonian's Department of Botany operated with

[12] Each case has 24 compartments.

about $400,000 in Fiscal Year 1968 (July 1967–June 1968), including granted as well as appropriated funds, which averages over $0.12/specimen for the approximately 3.25 million specimens on hand by this time. These funds covered salaries and operating funds for all research and curatorial activities, however, and probably no more than half of the total sum, i.e., about $0.06/specimen, was expended to support the U. S. National Herbarium per se. For Fiscal Year 1968, therefore, one might extrapolate that the USA spent at least $4 million on the nation's herbaria, including research and curation, and that at least $2 million of this went directly to the support of herbarium curation and service. The comparable figures for the whole world would be nearly $20 million and $10 million, respectively.

The routine operation of a herbarium includes accessioning, loaning and borrowing, exchanging, sorting and filing newly mounted specimens, identifying plants, answering public enquiries, and other activities. Figures on a few of these operations will indicate how rapidly the expense of operating a herbarium mounts.

The cost of sorting and filing newly mounted specimens varies greatly, depending especially on the training and experience of the person who does the work. Other things being equal, a professionally trained botanist can sort and file much more rapidly and efficiently than a technical assistant, but in either case the speed and efficiency are direct functions of experience. The botanist will earn two or three times more money per hour and should, therefore, be three or four times more efficient than the technical assistant, but this is not likely because the botanist will file less mechanically and will take time out to solve more problems. At the U. S. National Herbarium, where sorting and filing are shared by botanists and assistants, it costs a minimum of $0.10/specimen and an average closer to $0.15/specimen for the whole process, which, for 50,000 specimens/year, represents an annual bill of $5,000–$7,500 or even more. Extrapolating on the basis of $0.15/specimen and assuming that the annual growth rate of collections is about 1.5 percent (*see* "Size of Collections"), one can estimate that the yearly cost of sorting and filing newly mounted specimens is a minimum of $75,000 in the USA and $330,000 in the world. These

calculations also assume, for the sake of argument, that all newly accessioned specimens are being mounted and filed promptly.

Loan transactions constitute big business at the U. S. National Herbarium, where today about 1 percent of the total collection goes out on loan in a year. Personnel of different levels are required to process these loans, but the total cost, by my estimation, is equivalent to a professional man-year at $13,000–$15,000. Thus the cost averages upwards of $0.50/specimen. Extrapolating, the annual rate of loaning would be about 350,000 specimens in the USA, costing about $175,000, and about 1.5 million in the world, costing about $750,000. These are, of course, very rough estimates.

The cost of public service is, like all other activities of the herbarium, difficult to estimate. One important facet of public service is plant identification. During the most recent 10-year period for which there are statistics, the U. S. National Herbarium averaged about 18,000 identifications/year for professional and lay persons. This represents less than half of the requests actually made. At a very minimum this identification service has cost $1/specimen, and a more realistic average figure would be at least $2–$3/specimen. The rate depends on the percentage of the identifications made for professional persons, who require an authoritative precision not required by the public. By the time he consults both the collections and the literature, a botanist not infrequently spends an hour or two on a single specimen; therefore, the cost can mount quickly to $5–$20/specimen. In recent years, some Smithsonian botanists have identified up to 4,000 specimens/year, mostly for professional colleagues. Taking the rock-bottom figure of $1/specimen and the rate of identification of the National Herbarium, I estimate the annual bill for the USA to be something over $200,000 and for the world about $1 million. The true costs are probably double these figures at least.

Dividends

One would be foolish to attempt to put a dollar figure on the full value of the herbarium to science and society, because in a very real sense this value is incalculable. At the same time,

herbaria do cost big money, as we have seen, and the public has the right to ask, as it frequently does, what the payoff is. Curators are justified, therefore, if not duty bound, to consider what dividends can be reaped from their collections and activities.

The worth of the herbarium to the scientific community can be evaluated in part by the amount of money invested in herbarium-based research. With respect to the United States, some interesting data on research investment can be found in the statistics of the National Science Foundation. Over the last six years (1963–68), the NSF, through its Systematic Biology Program, has awarded grants totalling $10,653,500 for studies in systematic botany (excluding viruses and bacteria). This is an average of almost $1.8 million/year, and during the last two fiscal years (1967, 1968) the amount awarded has averaged about $2 million/year. Of the money awarded, about 40 percent ($4.25 million) has gone to floristic and monographic studies, which are vitally dependent on the herbarium, while another 40 percent has gone to studies that are much less dependent on the herbarium but are likely to require it at some stage just the same. In other words, about 80 percent of the money awarded has gone into researches that are to some degree herbarium-based. This represents about $1.4 million/year or, if only floristic and monographic researches are considered, about $0.7 million/year. The above figures are based only on grants made by the Systematic Biology Program. It must be added that environmental and other biologists who receive grants through other NSF programs frequently conduct researches that require the use of the herbarium. The money spent through the Systematic Biology Program represents, therefore, only the most direct and visible of NSF's investments in herbarium-based research.

Much herbarium-based research is done in the United States each year without financial support from the NSF. There probably are about 1,000 plant systematists in the United States. On the basis of the past two years the NSF would seem to be supporting only about 14 percent of these American taxonomists (about 140 out of 1,000). (To the 80 new grantees each year must be added about 60 continuing grantees; the average grant lasts about 21 months.) The 14 percent have been commanding

nearly $2 million/year, but they constitute the "rich cousins" of the taxonomic fraternity. Probably, the other 86 percent do not average more than 10–15 percent of the almost $15,000/man/year that the NSF-supported scientists have available for research. At 10 percent or $1,500/man for the other 86 percent, the annual investment for research in plant systematics in the United States becomes $3.3 million ($2 million from NSF for 140 systematists + $1.3 million from other sources for 860 systematists). The 10 percent estimate could be much too low, of course. Carrying our extrapolation to its conclusion, we can estimate that 80 percent of the $3.3 million, i.e., $2.64 million, goes into herbarium-based researches of some type, while 40 percent, i.e., $1.32 million, goes to the support of floras and monographs, which cannot be produced without the herbarium. Thus a $70 million herbarium investment supports $2.64 million worth of research each year, although much more research could be supported annually with the same investment.

There is another means of evaluating the worth of the herbarium to science in America. Given that the existence of the herbarium is vital to the existence of the discipline of plant systematics, we can say that in the United States today's 1,000 systematists are supported as a research fraternity by the $70 million herbarium investment. At an average salary of $12,000/year, the annual price tag of this fraternity is $12 million. Add to this the $3.3 million used to pay for their research, and we have a scientific enterprise costing $15 million annually that could not exist as we know it today without the historical investment in the herbarium.

The cost of a service is also a measure of the value of the service rendered. Thus in the previous section ("Investments and Costs") the costs to herbaria of storing and lending specimens for research and of identifying plants for scientists and the public, which probably are the two most important services of the herbarium, are discussed.

The public user community is essentially the citizenship at large, and its dependence on the herbarium can only be evaluated in terms of specific kinds of requests such as for plant identifications. At any large herbarium, identification, like specimen lending, is big business. The annual bill for identification

would be much higher if the manpower were available to meet the real demand.

Changing Role Of Herbarium

Historically, herbaria were the personal collections of private individuals who preserved plant specimens to document ceremonial or medicinal uses or to satisfy cultural or scientific curiosity. The collector, if a serious scholar, was both scientist and curator. He traded duplicate specimens with colleagues as a means of diversifying his own herbarium and of notarizing his own finds. A man of means (e.g., of royalty) could hire a curator and commission collectors to obtain the necessary specimens for duplicate exchange, but his herbarium remained a personal property for his own amusement and his curator's, if not his own, study.

The emergence of botany as a science in the 17th and 18th centuries invested dried plant collections with a new significance and thereby brought about the institutionalization of the herbarium. Private collecting has never ceased, of course, but today the herbarium is highly institutionalized. Not only is the herbarium an essential scientific institution, but in the organizational sense it has become a public institution, governed by museums, universities, botanical gardens, and other corporate bodies. The modern herbarium, in addition to being a place of research, is a large service bureau. As already indicated several times, herbaria in the aggregate represent big business, and running a major herbarium calls for businesslike methods. The private little collections that once could be known in their entirety and be managed "out-of-pocket" by their sole curators have become so massive in many cases that no single curator could hope to know their limits or to discharge all their tasks. Large herbaria require the cooperation of several to many curators.

The fact is that although more than four centuries have passed since the first institutional herbarium was formed curatorial mentality and practice are still characterized strongly by the personal entrepreneurship of a private collector. The transition from the personalized, private herbarium to the collective, public herbarium, with its corporate research and service responsi-

bilities extending over many generations of curators and citizens, has been made imperfectly at best in most instances. Curators, whether they have curated a small herbarium or some part of a large herbarium, have always tended to shape their collections according to their own scientific and management concepts. Often too little thought has been given to the implications of being part of a much larger system that must survive the lives and whims of individuals. Small, one-man herbaria may be able to withstand the consequences of generation after generation of subjective curation, but large herbaria must have objective standards or in time they become a hodgepodge of curatorial idiosyncrasies. Thus, a large herbarium, instead of being curated by a uniform, generalized system, may be curated as several autonomous or semi-autonomous fiefdoms. Sometimes each fiefdom has its own familial and generic concepts or filing system.

Some subjectivity is essential, of course, because in the final analysis the herbarium is not only a facility and a resource but also an instrument of taxonomic research. If the instrument has shaped the science, so has the science shaped the instrument. The science of systematic botany itself is changing, however, and becoming less descriptive. As it becomes less descriptive, it tends to become less subjective; therefore, the herbarium should become less a subjective instrument of research and more an objective source of information. Such evolution in function demands new ground rules for collection building and management.

The life cycle of plant taxonomy, whether one thinks of the historical development of the science or of the knowledge about a particular flora or group of plants, has had at least four recognizable phases thus far (cf. Valentine and Löve 1958): descriptive (exploratory), floristic-phytogeographic, systematic, and biosystematic (including chemosystematic). A fifth, ecosystematic phase is just beginning. These are relative states of progress in the development of taxonomic knowledge, of course, and as such describe not only chronological stages in time but also phases of activity going on simultaneously within the taxonomic community at any given period of time. Collection building has tended to reflect this changing cycle of taxo-

nomic approaches, i.e., the character of the collections being accumulated has been influenced by the type of taxonomy being done. Obviously, there is no perfect system for arranging the herbarium so that it will serve these five phases—or any other phases—of plant systematics equally well, nor can a curator change the physical arrangement of his herbarium to conform to the latest thinking every time some new research fad comes along. The bewildering array of systems and partial systems in use among herbaria today, which often are long since outgrown or overgrown and of which no two seem to be alike, stand like ancient shipwrecks as mute testimony to the navigational errors of past curators who tried to keep pace with the times by arranging part or all of their collection according to current taxonomic concepts, only to have these concepts change faster than they could rearrange the specimens consistently.

The herbarium first became a scientific institution when taxonomic botany, indeed all of biology, was almost entirely descriptive, and the principles of organization and use established then have largely dictated practice ever since. Through the years botanical exploration has been a chief stimulus for herbarium-founding, witness the geographical shift of focus of new herbarium development from Europe to North America and Asia and thence to Africa and South America in phase with the general exploration and development of these regions of the world. During the descriptive-exploratory stage the herbarium takes shape as a repository of exemplars of the new forms of plant life coming off the collector's conveyor belt from exotic regions. The descriptive or alpha taxonomist deftly and expertly sorts from this conveyor, sifting the known from the unknown. The known are filed and the unknown are described and published as quickly as possible. At this stage the paramount function of the herbarium is to provide, for purposes of identification and diagnosis, easy and logical access to the exemplars of already-described taxa, and the primary task of the curator-taxonomist is to keep his incoming material described up to date, which requires that he know his previous collections intimately and have them neatly classified and filed away.

The curator who likes to assign a place to every specimen has little difficulty in doing so while the herbarium is

high on diversity and low on variability in its representation of the plants in nature. As soon as a second specimen of a known taxon appears, however, the exemplar approach begins to break down, and each succeeding specimen further erodes the homogeneity of the taxon and complicates the task of identification and novelty-recognition. Therefore, specimens additional to the types not only have less value intrinsically than the types but also constitute in reality a nuisance factor because they obfuscate the nice boundaries that could be drawn on the basis of single exemplars. The pigeonhole mentality is difficult if not impossible to outgrow. For purely practical reasons every specimen must have a place to rest, and, regardless of the phase of taxonomic development, identification, comparison, and diagnosis tend to remain the primary functions of the herbarium and therefore dictate its arrangement. By the same token, the herbarium botanist faces the danger of becoming trapped with these functions, never having a chance to indulge in the broader aspects of systematics.

Once the majority of the novelties have been discovered, attention turns to floristics and phytogeography. In this second phase of taxonomy the curator-taxonomist monitors the conveyor of incoming material for new and interesting distribution records, and geography becomes a major parameter by which he tries to sort and arrange his specimens. Now the currency of study is not the taxonomic novelty, but the geographic novelty, with endemism, disjunction, and the ebb and flow of floristic or phytogeographic elements being major themes of interest. Generally, the curator-taxonomist will be especially interested in only one or a few regions; consequently, his subdivisions will be precise in these cases and very coarse for the rest of the world. In time, such gerrymandered systems become clumsy and meaningless as natural geographic arrangements; they also become loaded with political anachronisms as the boundaries of countries change. It probably is fair to say that hardly any herbarium in the world uses a fully modern geographic scheme of which it wholly approves. The geographic mentality fostered by this phase of taxonomic development can lead easily to absurd extremes in herbarium-packing of specimens of the same species for purposes of documenting local distribution.

The third or systematic phase raises taxonomy and the use of the herbarium above the level of pure description to the philosophy of relationships. The herbarium now becomes an active instrument of the curator-taxonomist as he tries to arrange the specimens according to how they should be classified, and, as mentioned before, most modern herbaria reflect some earlier system of classification. A large herbarium hardly is amenable to further manipulation as new systems are proposed. Furthermore, seldom is it possible even to keep current the older system in use, if it is a phylogenetic one.

In the fourth, biosystematic phase, we see the need for large, in-depth collections (population samples) of the taxa under study. Most curators are justifiably reluctant to store large samples of individual taxa because they cannot cope physically with the specimens. Moreover, in terms of the traditional and still prime functions of the herbarium, this represents unconscionable duplication. Yet no biosystematist wants to see his samples treated as "duplicates" and split up for inter-institutional exchange. Also, the biosystematist needs a herbarium that provides easy access to other kinds of specimen data than the traditional name and place of collection.

The recent, ecological phase of systematics has only begun. The next decade will bring, I believe, a solid alliance between taxonomists and ecologists and the emergence of what can be called "ecosystem taxonomy." Surely the International Biological Program (IBP) will develop intense pressures for this. The ecosystem taxonomist, as contrasted with his predecessors, will be less concerned with the absolute precision of his identifications and the phylogenetic hierarchy of his organisms and more concerned with the general, statistical patterns of distribution as they correlate with environmental factors, including pollutants; he will also be concerned especially with the interrelationships and coevolution of different plants and of plants and animals, including man. Thus he will need a much more flexible access to the data locked up in the herbarium than we now have; furthermore, he will call for more sophisticated ecological data-keeping.

The picture is clear. The herbarium was designed for the purposes of a descriptive science that dealt mainly with the

questions of what and where, but it has had to survive fundamental changes in this science and now finds itself in an era when the questions are mainly how and why. The fact is that the herbarium has never really adapted to the modern biosystematic and ecological era, and unless it does it will become largely irrelevant in time. We have not yet overcome the problem of providing flexible, multi-access to a data bank that can have only one physical structure, ordered by one parameter, in this case the scientific name. The sharp decline in the founding of new herbaria since the 1920s seems only to be a specialized reflection of a general decline in descriptive biology. The herbarium is after all the chief resource of the descriptive plant systematist, and any deterioration of his status inevitably will decrease the demand for the tools of his trade. Collectors have pushed to the limits of the temperate regions and pressed on into the tropics. Perhaps, especially with new temperate and tropical flora projects in progress and with greatly expanded tropical exploration and research, the 1960s and 1970s will prove in retrospect to have reversed the downward trend in descriptive systematics and herbarium-founding, but this seems doubtful, given the present-day climate of biology and science. Despite the secondary resurgence of such activity particularly in tropical regions, the downward trend appears to be inevitable and irreversible. The golden age of herbarium-founding, has passed.

Strategy For The Future

As a physical creature, the herbarium has grown through more than 400 years until today it has achieved menacing proportions. Not just a few curators are virtually enslaved by the sheer burden of the routine daily transactions and public service, when in fact they should be practicing science. At the same time the science, too, has changed, so that altogether the forces of change and growth have conspired to make it difficult for today's herbarium botanist to be both curator and scientist. Descriptive taxonomy is a fairly natural and easy byproduct of curatorial activities, and it thrives on a constant inflow of new material. To the biosystematic, ecosytematic, or experimental taxonomist, however, curation is largely an encum-

brance, a service to perform as the price of being a professional taxonomist.

The herbarium, no less than the library, continues to fulfill an absolutely vital role in science and in practical human affairs as a data bank and information system, even though increasingly it creaks from an overburdened, arthritic curatorial machinery and suffocates in the clutch of the time-honored but outmoded and inflexible ground rules of research and public service. Being an institutional giant and in many respects an overaged one, it faces hazards of survival that are not small. There are those today—and their number is growing—who see the herbarium as an economic millstone and an intellectual dinosaur in the modern scheme of science. The truth, however, is that the herbarium is beginning to be tapped for a whole new generation of scientific and public questions. As the concern rises about the quality of our natural environment and the ecological principles that control this quality, public officials are being forced to come up with instant ecological histories and forecasts. The conservation of natural resources, including plant and animal communities and particularly endangered species, has become a burning public concern. Ecology and conservation quickly reduce themselves to relationships among organisms. Museums, herbaria included, are the repositories of vast amounts of raw and standardized data about the earth's organisms. The alert curator is not surprised, therefore, that the rising emphasis on environmental biology is giving new significance and urgency to the business of museums. Unfortunately, herbaria, like museums in general, are not ready for the increased demands of the era of environmental biology.

The time for new premises and strategies is upon us. The principal challenge is to "get with it" in trying to reshape the herbarium for the age of environmental biology and the computer, to meet the contingencies not only of a changing science (biosystematics, chemosystematics, ecosystem taxonomy, etc.) but also of a moody, ecologically conscious society who want to know how to survive. We must hope that the world's herbaria will unite at different levels (local, regional, national, international) to develop a blueprint for action. Meanwhile, several of the necessary steps to be taken are obvious.

(1) Every herbarium is both a scientific organization and a public service bureau, and the time has come to accept the full import of this dual nature and reorganize accordingly. The day is past when the taxonomic scholar can be both scientist and curator. Our goal must be to isolate the functions of the herbarium, which are the tasks of the curator, from the research of the herbarium, which is the responsibility of the scientist, i.e., taxonomic scholar. Only in this way can the herbarium rise to meet the increasing service demands and at the same time remain a viable scientific research institution.

The scientific and the service functions of the herbarium can and should be performed by different staffs. As a public service bureau, the herbarium should be organized like a modern library and staffed by a cadre of professionally trained, librarian-like technical experts and aides who specialize in the herbarium's functions, e.g., accessioning, filing, lending, identifying, etc. Libraries are not organized on the premise that only scholars can order, purchase, catalog, shelve, and loan the books, and neither should herbaria be organized on this premise. After an overall systems and cost analysis of input, processing, storage, and output, herbaria should departmentalize and staff appropriately. Non-research personnel, whose professional rewards do not depend on publication, can be trained to perform most if not all curatorial and public service functions of the herbarium just as well as, if not better than, research scientists. As a scientific organization the herbarium should become an institute for advanced studies, organized and staffed according to disciplines and programs, not by curatorial responsibilities. A strong link and intimate cooperation should be maintained between the curators and the scientists, however, because the latter will need to continue to guide curatorial policy.

(2) The computer must be brought into the herbarium without further delay. A new day has dawned in information science, and the meaning of this for museums has been pointed out repeatedly in recent years (Sokal and Sneath 1966, Squires 1966, Crovello 1967, Rogers *et al.* 1967, Soper and Perring 1967). The constant growth of collections impels us to find more efficient means of storing the specimens and accessing the data. A computer system for information retrieval (IR) provides the

ideal answer to the problem of data access and allows great freedom in the physical arrangement of the specimens. Data can be retrieved without necessarily taking recourse to the specimens, and the cross-indexing power of the computer enables one to find specimens when necessary regardless of the physical storage system. The latter capability makes the computer an important tool for managing herbarium transactions (loans, exchanges, accessions, etc.) as well as for providing flexible access to the embedded data. Various control lists can be generated that profile the strengths and weaknesses of the herbarium with respect, for example, to geographic or taxonomic representativeness of the collections. Such profiles could put curatorial decision-making on a much more objective basis, especially as regards the accessioning of new material.

Every specimen carries both objective data (e.g., geographic and other label data), which may require little or no professional interpretation, and subjective data (e.g., morphological traits), which may require highly professional interpretation that can only be made after study of the specimen itself. In a manual system, neither kind of data can be retrieved without actually seeing the specimen, and this requires transporting either the specimens to the investigator or the investigator to the specimens. An IR system can bring the objective data from the specimens to the investigator without burdening anyone with handling the specimens themselves. Once a magnetic record of a collection is created, one can in effect rearrange an entire herbarium just to answer a single question and do it, perhaps, with less effort and cost than to process a loan of a few hundred specimens. Even with only a few descriptors per specimen recorded, many combinations are possible, and one is able to ask complex questions and thereby to locate precise subsets of specimens or compile specific data from randomly scattered places in the herbarium—all without moving a single specimen. The investigator is free to decide on the basis of his answer whether he needs to see the specimens. To be sure, there are certain risks to retrieving and using data without seeing the specimens; for example, the risk of misidentification. Nevertheless, there are many instances in scientific research and public service when these risks are tolerable.

Herbarium curators have in large measure lost control of their vast data bank, now comprising an unmanageable 200 million specimens or more over the world. Given the advanced state of computer technology today, there scarcely is a defense any longer for continuing to add to this overburden of specimens without simultaneously capturing the data for management and retrieval. The high cost of developing and implementing an electronic data processing (EDP) system will prohibit indiscriminate input and force curators to make some hard decisions about the specimens and data to be preserved. Thus the process of computerizing data can serve as a much-needed quality control mechanism. If a specimen does not carry data worth computerizing, then it can hardly be worth preserving and filing in the herbarium for all time. No longer can we afford to presume on our successors by adding to their future curatorial burden under the blithe assumption that while the specimen was not worth our time and money it might be worth theirs.

The place to begin is with select subsets of our herbarium collections (e.g., types) and with newly accessioned material. It is doubtful whether herbaria will ever have the resources to input the whole 200-million-specimen backlog, and, considering the quality of the data of many older specimens, one can raise serious questions as to whether this should be done even if the resources were available. Instead, we must concentrate on what I might call the "forelog."

(3) All herbarium operations need to be examined carefully and modernized if necessary, not only with respect to EDP, but also in the light of the current state of science, the growing shortage of staff and space, and the growing public and professional demand for herbarium-based information. We have seen that herbarium operations today are expensive; even a 1 percent increase in efficiency would effect significant savings. Courage will be needed to abridge or abandon outmoded practices. To cite one prominent example, the time-worn specimen exchange procedures badly need scrutiny and appropriate streamlining. Particularly the larger herbaria need to shake loose from the iron grip of the book-balancing exchange mentality.

In the present day, duplicate exchange is in some respects an

anachronism. The world hardly lacks for large, representative herbaria, and the number of herbaria has increased to the point where it is difficult if not impossible for an institution to draw rational limits to its exchanges. Today's rapid means of travel and communication leave little excuse for building up numerous herbaria with duplicates of the same collections. In the framework of population biology, moreover, it is questionable whether there is such a thing as a "duplicate" specimen.

One way to modernize exchange practice would be to establish a cooperative exchange center or clearinghouse which manages transactions by computer and provides specimen-sorting service as needed. Each herbarium would trade and balance books with the system, not with every herbarium from which it happened to receive duplicates. The exchange center could abide by the wishes of donors in distributing their sets of specimens by sending them only to specified recipients. On the contrary, the center could honor the wishes of recipients by sending them only the kinds of material they requested. In many cases, specimens might be exchanged directly between donor and recipient after clearing the transaction with the exchange center. Such a system surely would reduce the inefficiency and increase the effectiveness and order of the exchange process and thereby serve the general good. It could only be established by cooperative effort, however.

(4) The herbarium needs strengthened intellectual foundations, including ties with some of the newer biological and environmental disciplines. This can be achieved by exploiting the herbarium through EDP systems as a vital data bank for biologists other than systematists and by organizing broad, preferably interdisciplinary research programs that require herbarium resources and data and at the same time engender the kind of national and international planning and cooperation that will give the world's herbaria as a group more cohesion, singular and self-respecting voice, and 20th-century relevance. Given the present experimental and molecular scientific climate, we can say that the herbarium is truly at the crossroads, and it will surely fall if it loses its intellectual underpinnings and fails to adapt to the communications revolution by com-

puterizing. Literally, therefore, "united we stand and divided we fall."

(5) Finally, the herbarium needs a new, more solid financial base. This means greater national support, which can come only through cooperative planning. Herbaria are a special kind of national research archive and instructional tool, deserving of regular, dependable subsidy. National support cannot be sought on any rational basis, however, until herbaria show a willingness to operate less like competitive, private enterprises and more like the units of a functioning system. Every herbarium that ever makes a loan or accepts an exchange or gift of specimens is part of a national and international network, participating in the commerce of taxonomy. Any government would be less than prudent to sink large sums of money—and the herbarium is a colossus that could absorb unlimited funds—into its herbaria without first requiring conscious cooperation that takes cognizance at a planning level of the actual network formed by the existing herbaria and divides the responsibilities so that duplication of resources and services is minimized.

In the United States federal support for herbaria over the years has been trivial compared to the needs, and unfocussed with respect to the national interest. The time is ripe for a national strategy. During the 6-year period from 1963 to 1968, the Systematic Biology Program of the National Science Foundation granted less than 2 percent of its funds for collection maintenance per se, and for botany this amounted to about $30,000/year, totalling less than $200,000 out of $10 million for the whole period. If a matching dollar had been put up for every dollar spent on herbarium research, the amount would have totalled at least $4 million and perhaps as much as $8 million—or $0.7–$1.3 million/year. This would have brought an average of about $15,000–$30,000 to every herbarium in the country during 1963–1968. Surely, for every dollar spent on fieldwork there should be a matching dollar for collection curation. Too often research proposals in systematic botany take the availability of herbarium collections and services for granted, when in fact they should be asking for the funds to purchase this accessibility and service just as they ask, for example, for funds to pay publication costs. Ironically, curators as curators are prob-

ably the most thanked people in biology, but as individuals they are taken for granted for the many thankless tasks they must perform personally.

It would be unfair to imply that NSF support for herbaria has been confined to the relatively few dollars that have come directly through the Systematic Biology Program. In addition there have been grants for facilities and more recently the Office of Science Information Services at NSF has been supporting the development of computer systems for biological data. Nevertheless, the total investment has certainly not met the needs.

Many American herbaria, especially in the smaller colleges and universities, serve primarily a teaching function. Teaching herbaria are vital to the nation's science programs and should be supported as educational facilities. Their subsidy should be commensurate to the teaching programs they support. The small teaching collection has a way of escalating into a larger and larger research collection, demanding space and resources that exceed the teaching value of the herbarium to its home institution. Such escalation may show commendable industry on the part of the local curator, but it may also pose hard questions about duplication of resources for the national funding agency that is asked to pick up the tab.

At present the United States has only one National Herbarium, but many other American herbaria receive federal support. What is needed as a framework for greater federal support is for all university, government, and private research herbaria in this country to organize themselves into a full network of national herbaria. Then each could be recognized and financed to fulfill a particular role. Some herbaria might concentrate on broad geographic and systematic coverage, while others concentrate on particular regions or systematic groups. State and local governments might be induced to support a complementary network of state and local herbaria, perhaps with some matching federal funds if national scientific standards and objectives were being met. Any national system must steer a middle course between centralization and decentralization of resources and management. The lesson of the Berlin herbarium, destroyed in World War II, has taught taxonomists the wisdom

of a certain amount of decentralization and duplication of important collections.

Part of the price of increased federal support, it is clear, will be the loss of a certain amount of autonomy, because herbaria will have to agree on their roles and stick to them. While there may be no limit to the number of small teaching herbaria that can serve a useful function, a nation only needs so many large research herbaria of a given geographical or systematic specialty. The latter statement is especially true in a day when the costs of transporting scientists or specimens may be cheaper than the costs of maintaining essentially duplicate research herbaria. Thus the further development of teaching and research herbaria cannot be left to chance if the United States is to have a national strategy for support. The whole point of a national plan would be, not to compel anyone to do anything, but to identify the role that each herbarium should play and then subsidize the herbarium accordingly.

Progress Toward Goals

The ideas presented here certainly are not new (e.g., *see* Sokal and Sneath 1966). On an individual basis, many herbaria have taken or attempted some of the steps proposed, in some cases long ago. But the destiny of the herbarium as an institution can only be decided by cooperative planning and action. Herbaria must unite to persuade national policy planners to support them, and they must unite to train a pool of technical experts who can take the burden of curation off the backs of the scientists. Operational procedures like duplicate exchange cannot be modernized unilaterally. A herbarium only hurts itself if it tries this. Likewise, no single herbarium has the necessary resources or force of authority to develop and implement a herbarium-wide data processing system. On the international level, the International Bureau for Plant Taxonomy and Nomenclature, with headquarters in Utrecht, Netherlands, has done much to increase cooperation. Many of the problems can be solved only by active collaboration at the national level, however. Eventually, such national collaboration can lead to more formal international planning and cooperation. Fortunately, at present a number of museum and herbarium di-

rectors in the United States have become quite concerned about the future of museum collections and of systematic biology in general, and two or three studies are underway to determine the feasibility of greater national cooperation and financial support in the USA.

Within the last few years several pilot projects in applying electronic data processing to museum collections have been undertaken, which must be nurtured and expanded to embrace all herbaria. The Smithsonian Institution now has programs going to computerize data from selected portions of its collection of about 60 million specimens. One of the projects, headed by Mason E. Hale, is designed to produce an automated register of type holdings in the U. S. National Herbarium. The cooperation of other herbaria is being sought so that the Type Register can in time become a union list of worldwide holdings. Another highly significant development is the TAXIR (Taxonomic Information Retrieval) system and research program of David J. Rogers and group at the University of Colorado, financed by the National Science Foundation. Two other noteworthy data-automation projects are under way at the herbarium of the National Museum of Canada in Ottawa (James H. Soper) and at the Herbario Nacional del Instituto de Biologia, Universidad Nacional de México (Arturo Gomez-Pompa).

North American plant taxonomists have just embarked on an immense new cooperative program, Flora North America, which holds much promise for bringing about greater herbarium coordination. Flora North America is organized to produce a concise treatise of the vascular plants of the continent north of Mexico, but the project is deeply committed to bringing flora-preparation into the computer age. Information systems concepts are being exploited to develop a flora data bank, which inevitably must involve the herbarium and the botanical literature (Morse *et al.* 1968, Shetler 1969). Such a data bank should help to translate the herbarium to many people and to make it more relevant than ever as we enter the era of environmental biology.

Conclusion

The quantitative growth of the world's herbaria has overwhelmed us and become an end in itself, such that we spend all of our time packing away specimens for a research day that never comes. At the same time we find ourselves incapable of retrieving the most elemental information. The time is here if not past when a qualitative innovation in herbarium building and management is needed. To face the future the world's herbaria need a new strategy based squarely on electronic data processing systems and a businesslike understanding of the service and storage demands of the modern herbarium. The computer makes possible a whole new concept of data banking in the herbarium—the first real innovation since the specimen case replaced the herbalist's scrapbook—and the environmental biologist and ecosystem ecologists have already created the demand for this kind of data access. The herbarium community must unite in phrasing its needs and organize to meet and support them cooperatively. Today herbarium botany, like big science generally, requires big money, and this calls for big but responsible organizing premises and programs. Otherwise, the herbarium ceases to be relevant in terms that the taxpayer or even another scientist can understand.

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TABLE 1. Distribution of Herbarium Resources by Continent or Region. I. Specimens.

Continent or Region[1]	Number of Herbaria[2] (Percent)	Number of Specimens (Percent)	Herbaria Reporting Number Specimens[3] (Percent)	Average Number Specimens/ Herbarium[4]
North America	291 (31.2)	36,125,822 (24.4)	250 (86)	144,503
Europe	274 (29.4)	77,609,223 (52.5)	200 (73)	388,046
Asia	114 (12.2)	8,182,524 (5.5)	70 (61)	116,893
South America	75 (8.0)	3,150,211 (2.1)	59 (79)	53,393
Africa	54 (5.8)	2,417,483 (1.7)	49 (91)	49,336
British Isles	53 (5.7)	14,355,161 (9.7)	38 (72)	377,767
Malaysia–N. Guinea	18 (1.9)	1,735,000 (1.2)	14 (78)	123,929
Australia	16 (1.7)	3,149,000 (2.1)	15 (94)	209,933
West Indies	13 (1.4)	218,700 (0.15)	11 (85)	19,882
Mexico–C. America	11 (1.2)	243,007 (0.16)	7 (64)	34,715
New Zealand	7 (0.8)	472,500 (0.32)	6 (86)	78,750
Pacific Islands	3 (0.3)	190,000 (0.13)	2 (67)	95,000
Madagascar	3 (0.3)	64,000 (0.04)	3 (100)	21,333
Greenland	1 (0.1)	——	0 (0)	——
TOTAL	933 (100)	147,912,631 (100)	724 (78)	204,299

[1] According to arbitrary geographic breakdown: Europe includes Iceland, Azores, and Madeira Islands; Asia includes Japan and Taiwan; Pacific Islands include Hawaii, Fiji, and British Solomon Islands; and Mauritius and the Seychelles are lumped with Madagascar.

[2] Tables 1–4 are ranked by decreasing number of herbaria.

[3] Percentage computed from: Herbaria Reporting Number Specimens/Number of Herbaria.

[4] Number of Specimens/Herbaria Reporting Number Specimens.

TABLE 2. Distribution of Herbarium Resources by Continent or Region. II. Manpower.

Continent or Region[1]	Number of Staff (Percent)	Herbaria Listing Staff[2] (Percent)	Average Number of Staff/ Herbarium	Average Number of Specimens/ Man[3]	Founding Dates[4]	
					Oldest	Youngest
North America	799 (25.3)	262 (90)	3.0	47,384	1772 (SC)	1963 (HNT)
Europe	1151 (36.4)	231 (84)	5.0	77,879	1545 (PAD)	1963 (AAU)
Asia	303 (9.6)	82 (72)	3.7	31,635	1793 (CAL)	1962 (BUA)
South America	350 (11.1)	64 (85)	5.5	9,763	1808 (RB)	1963 (UB)
Africa	174 (5.5)	54 (100)	3.2	15,311	1855 (SAM)	1962 (UNN)
British Isles	179 (5.7)	45 (85)	4.0	94,971	1753 (BM)	1955 (KLE)
Malaysia–N. Guinea	56 (1.8)	16 (89)	3.5	35,408	1817 (BO)	1954 (CLP)
Australia	61 (1.9)	16 (100)	3.8	55,064	1857 (MEL)	1954 (AD,NT)
West Indies	23 (0.7)	7 (54)	3.3	6,051	1846 (TRIN)	1958 (FPDB)
Mexico-C. America	18 (0.6)	6 (55)	3.3	10,415	1887 (CR)	1950 (ITIC)
New Zealand	25 (0.8)	6 (86)	4.2	18,900	1865 (WELT)	1946 (OTA)
Pacific Islands	13 (0.4)	3 (100)	4.3	21,923	1889 (BISH)	1933 (SUVA)
Madagascar	6 (0.2)	2 (67)	3.3	6,400	1737 (MAU)	1962 (SEY)
Greenland	——	—	—	—	1906 (DISKO)	1906 (DISKO)
TOTAL	3158 (100)	794 (85)	4.0	54,370	1545	1963

[1] Geographic order as in Table 1.

[2] Percentage computed from ratio of Herbaria Listing Staff/Number of Herbaria (*cf.* Table 1).

[3] Computed from ratio of Average Number Specimens per Herbarium/Average Number of Staff per Herbarium (before rounding) rather than from ratio of Number of Specimens/Number of Staff, because more herbaria reported number of staff than number of specimens (*cf.* Table 1).

[4] Herbaria are identified in this and all subsequent tables by standard abbreviations of Lanjouw and Stafleu (1964).

TABLE 3. Distribution of Herbarium Resources by Country.[1] I. Specimens.

Country	Number of Herbaria (Percent)	Number of Specimens (Percent)	Rank by Number of Specimens	Herbaria Reporting Number of Specimens (Percent)	Average Number Specimens/ Herbarium
1. United States of America	244 (26.2)	33,629,722 (22.7)	1	210 (86)	160,142
2. Great Britain	50 (5.4)	13,954,661 (9.4)	3	35 (70)	398,705
3. Canada	48 (5.1)	2,656,100 (1.8)	13	41 (85)	64,783
4. U.S.S.R.	43 (4.6)	10,577,997 (7.2)	4	26 (60)	406,846
5. France	42 (4.5)	14,617,600 (9.9)	2	24 (57)	609,067
6. Italy	38 (4.1)	5,174,677 (3.5)	8	27 (71)	191,655
7. Brazil	37 (4.0)	1,020,743 (0.7)	28	31 (84)	32,927
8. China	33 (3.5)	1,665,000 (1.1)	20	9 (27)	185,000
9. Germany	32 (3.4)	7,933,800 (5.4)	5	24 (75)	330,575
10. Japan	21 (2.3)	2,297,000 (1.6)	15	15 (71)	153,133
11. Argentina	18 (1.9)	1,625,800 (1.1)	21	14 (78)	116,129
12. Australia	16 (1.7)	3,149,000 (2.1)	11	15 (94)	209,933
13. India	16 (1.7)	1,820,452 (1.2)	18	13 (81)	140,035
14. South Africa	14 (1.7)	1,105,338 (0.7)	25	14 (100)	78,953
15. Austria	13 (1.4)	3,712,000 (2.5)	10	10 (77)	371,200
16. Portugal	13 (1.4)	1,280,502 (0.9)	23	10 (77)	128,050
17. Sweden	11 (1.2)	7,727,000 (5.2)	6	8 (73)	965,875
18. Switzerland	11 (1.2)	6,960,000 (4.7)	7	7 (64)	994,286
19. Spain	10 (1.1)	982,000 (0.7)	29	8 (80)	122,750
20. Czechoslovakia	9 (1.0)	4,550,000 (3.1)	9	7 (78)	650,000
21. Finland	9 (1.0)	2,018,300 (1.4)	16	9 (100)	224,256
22. Netherlands	9 (1.0)	2,736,380 (1.8)	12	9 (100)	304,042
TOTAL[2]	737 (79.0)	131,194,072 (88.7)	—	566 (77)	231,792

[1] Table includes only countries with 9 or more herbaria reporting; average number of herbaria/country is 9. Statistics organized as in Table 1.
[2] Totals cover only herbaria in table, but percentages are based on comparisons with totals for all herbaria.

TABLE 4. Distribution of Herbarium Resources by Country.[1] II. Manpower.

Country	Number of Staff (Percent)	Rank by Number of Staff	Herbaria Listing Staff (Percent)	Average Number of staff/ Herbarium	Average Number of Specimens/ Man	Founding Dates	
						Oldest	Youngest
1. United States of America	667 (21.1)	1	219 (90)	3.0	50,419	1772 (SC)	1963 (HNT)
2. Great Britain	171 (5.4)	3	42 (84)	4.1	81,606	1753 (BM)	1955 (KLE)
3. Canada	140 (4.4)	5	44 (92)	3.2	18,972	1820 (MTMG)	1958 (SAFB)
4. USSR	122 (3.9)	7	25 (58)	4.9	86,705	1770 (MW)	1947 (CHIS, PZV, TAA)
5. France	220 (7.0)	2	35 (83)	6.3	66,444	1635 (P,PC)	1958 (ABT)
6. Italy	115 (3.6)	8	31 (82)	3.7	44,997	1545 (PAD)	1960 (TSB)
7. Brazil	166 (5.3)	4	32 (86)	5.2	6,149	1808 (RB)	1963 (UB)
8. China	33 (1.0)	21	9 (27)	3.7	50,455	1929 (SYS)	1950 (PE)
9. Germany	102 (3.2)	9	30 (93)	3.4	77,782	1751 (KR)	1960 (HEID)
10. Japan	71 (2.2)	13	21 (100)	3.4	32,352	1875 (TH)	1958 (MAK)
11. Argentina	123 (3.9)	6	17 (94)	7.2	13,218	1812 (BA)	1955 (BAFC)
12. Australia	61 (1.9)	15	16 (100)	3.8	55,064	1857 (MEL)	1954 (AD, NT)
13. India	84 (2.7)	12	14 (88)	6.0	21,672	1793 (CAL)	1956 (ASSAM, BSD, BSI)

[1] Same order of countries as in Table 3; statistics organized as in Table 2. Other countries with 20 or more staff, according to rank and with number of herbaria in parentheses, are: 22nd, Belgium (31); 24th, Hungary (25), New Zealand (25); 25th, Denmark (24), Turkey (24); 26th, Egypt (21), Philippines (21); 27th, Poland (20).

TABLE 4. (*Continued*)

Country	Number of Staff (Percent)	Rank by Number of Staff	Herbaria Listing Staff (Percent)	Average Number of Staff/ Herbarium	Average Number of Specimens/ Man	Founding Dates	
						Oldest	Youngest
14. South Africa	53 (1.7)	16	14 (100)	3.8	20,855	1855 (SAM)	1942 (RUH)
15. Austria	45 (1.4)	17	12 (92)	3.8	82,489	1748 (W)	1925 (HALLST)
16. Portugal	64 (2.0)	14	12 (92)	5.3	20,008	1772 (COI)	1948 (LISC)
17. Sweden	97 (3.1)	11	11 (100)	8.8	79,660	1758 (S)	1948 (SPL)
18. Switzerland	41 (1.3)	18	10 (91)	4.1	169,756	1588 (BAS)	1931 (ZSS)
19. Spain	38 (1.2)	19	8 (80)	4.8	25,000	1781 (MA)	1945 (SANT)
20. Czechoslovakia	34 (1.1)	20	7 (78)	4.9	133,824	1875 (PRC)	1940 (SLO)
21. Finland	30 (0.9)	23	9 (100)	3.3	67,277	1828 (H)	1934 (HEL)
22. Netherlands	98 (3.1)	10	9 (100)	10.9	27,922	1575 (L)	1923 (FNM)
TOTAL Based on Table 4	2,575 (82)	1–21, 23	627 (85)	4.1	50,949	1545	1963
TOTAL Based on All Countries	3,158 (100)	1–45	794 (85)	4.0	46,837	1545	1963

TABLE 5. Oldest and Youngest Herbaria.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1750		
1.	Padua (PAD), Italy	1545	229,000
2.	Rome (RO), Italy	1566	400,000
3.	Bologna (BOLO), Italy	1567	———
4.	Leiden (L), Netherlands	1575	1,800,000
5.	Basel (BAS), Switzerland	1588	200,000
6.	Paris (P), France	1635	5,000,000
7.	Paris (PC), France	1635	1,200,000
8.	Floriana (ARG), Malta	1675	10,000
9.	Siena (SIAC), Italy	1691	492
10.	Amsterdam (AMD), Netherlands	1700	175,000
11.	Torino (TO), Italy	1729	50,000
12.	Reduit (MAU), Mauritius	1737	13,500
13.	Vienna (Wien: W), Austria	1748	2,500,000
	II. Founded in 1959–63[1]		
1.	Addis Ababa (ETH), Ethiopia	1959	6,000
2.	Tampa (USF), Florida, USA	1959	48,000
3.	Victoria (SCA), Cameroun	1959	1,400
4.	Arcadia (LASCA), California, USA	1960	25,000
5.	Heidelberg (HEID), Germany	1960	———
6.	Monrovia (LIB), Liberia	1960	2,500
7.	Trieste (TSB), Italy	1960	11,000
8.	Baghdad (BUA), Iraq	1962	5,000
9.	Nsukka (UNN), Nigeria	1962	———
10.	Port Victoria (SEY), Seychelles	1962	500
11.	Aarhus (AAU), Denmark	1963	25,000
12.	Brasilia (UB), Brazil	1963	20,000
13.	San Marino (HNT), California, USA	1963	500

[1] All of these but the Tampa herbarium first appeared in *Index Herbariorum* with the 5th edition (1964); the Tampa herbarium was reported in the 4th edition (1959) but without data.

TABLE 6. Herbaria Founded in Europe since 1950 (1951–63).[1]

	Location	Year of Founding	Number of Specimens
1.	Berlin (BSP), Germany	1955	3,200
2.	Avon (ABT), France	1958	20,000
3.	Funchal (MADJ), Madeira	1958	1,500
4.	Heidelberg (HEID), Germany	1960	———
5.	Trieste (TSB), Italy	1960	11,000
6.	Aarhus (AAU), Denmark	1963	25,000

1 The earliest 12 herbaria to be founded in Europe are listed in Table 5.

TABLE 7. Oldest and Youngest Herbaria of the British Isles.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1850		
1.	London (BM), England	1753	———
2.	Cambridge (CGE), England	1761	450,000
3.	Edinburgh (E), Scotland	1761	2,000,000
4.	Glasgow (GL), Scotland	1780	170,000
5.	Dublin (DUB), Ireland	1790	25,500
6.	Bristol (BRISTM), England	1820	13,400
7.	Manchester (MANCH), England	1821	3,000,000
8.	York (YRK), England	1822	8,000
9.	Norwich (NWH), England	1825	20,000
10.	Warwick (WAR), England	1836	6,000
11.	Torquay (TOR), England	1844	———
12.	Ipswich (IPS), England	1846	15,000
	II. Founded since 1950 (1951–63)		
1.	Exeter (EXR), England	1953	25,000
2.	Keele (KLE), England	1955	1,000

TABLE 8. Oldest and Youngest Herbaria of North America and the West Indies.[1]

	Location	Year of Founding	Number of Specimens
	I. Founded before 1850		
1.	Winston–Salem (SC), North Carolina	1772	600
2.	Charleston (CHARL), South Carolina	1773	———
3.	Middlebury (MID), Vermont	1800	3,000
4.	Philadelphia (PH), Pennsylvania	1812	1,000,000
5.	Montreal (MTMG), Quebec	1820	55,000
6.	Philadelphia (PHIL), Pennsylvania	1821	———
7.	Geneva (DH), New York	1822	16,000
8.	Boston (MCP), Massachusetts	1823	14,000
9.	West Chester (DWC), Pennsylvania	1826	12,000
10.	Amherst (AC), Massachusetts	1829	84,000
11.	Albany (NYS), New York	1836	430,000
12.	Ann Arbor (MICH), Michigan	1838	1,000,000
13.	Saint John (NBM), New Brunswick	1842	15,000
14.	Madison (WIS), Wisconsin	1849	360,000
	II. Founded since 1950 (1951–63)		
1.	Calgary (UAC), Alberta	1951	12,000
2.	Sioux Falls (AUG), South Dakota	1951	1,000
3.	Calgary (CFB), Alberta	1952	5,000
4.	Halifax (NSPM), Nova Scotia	1952	———
5.	Ottawa (CCO), Ontario	1952	10,000
6.	Quebec (QFB), Quebec	1952	12,000
7.	Baton Rouge (LSUM), Louisiana	1954	5,000
8.	Saint John's (NFLD), Newfoundland	1954	8,000
9.	Chicago (CHI), Illinois	1955	20,000
10.	Swarthmore (SWC), Pennsylvania	1955	4,200
11.	Mayaguez (FPDB), Puerto Rico	1958	4,000
12.	Saskatoon (SAFB), Saskatchewan	1958	2,000
13.	Tampa (USF), Florida	1959	48,000
14.	Arcadia (LASCA), California	1960	25,000
15.	San Marino (HNT), California	1963	500

[1] No herbaria were founded in Mexico or Central America during these years.

TABLE 9. Oldest and Youngest Herbaria of Asia.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1900		
1.	Calcutta (CAL), India	1793	1,000,000
2.	Dehra Dun (DD), India	1816	300,000
3.	Peradeniya (PDA), Ceylon	1817	85,000
4.	Eskisehir (ESK), Turkey	1832	725
5.	Coimbatore (MH), India	1874	124,525
6	Tokyo (TH), Japan	1875	10,000
7.	Sapporo (SAP), Japan	1876	130,000
8.	Sapporo (SAPA), Japan	1876	85,000
9.	Tokyo (TI), Japan	1877	500,000
10.	Hong Kong (HK), Hong Kong	1878	30,000
11.	Simonoseki (YAM), Japan	1883	12,000
12.	Tomsk (TK), USSR	1885	357,000
13.	Rawalpindi (RAW), Pakistan	1893	60,000
	II. Founded since 1950 (1951–63)		
1.	Istanbul (ISTO), Turkey	1952	2,800
2.	Allahabad (BSA), India	1955	7,072
3.	Yokohama (YNU), Japan	1955	10,000
4.	Dehra Dun (BSD), India	1956	22,125
5.	Poona (BSI), India	1956	85,000
6.	Shillong (ASSAM), India	1956	70,130
7.	Tokyo (MAK), Japan	1958	380,000
8.	Baghdad (BUA), Iraq	1962	5,000

TABLE 10. Oldest and Youngest Herbaria of Australasia and the Pacific Islands.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1900		
1.	Bogor (BO), Indonesia	1817	1,000,000
2.	Melbourne (MEL), Australia	1857	1,500,000
3.	Wellington (WELT), New Zealand	1865	200,000
4.	Christchurch (CANTY), New Zealand	1867	20,000
5.	Singapore (SING), Malaya	1875	400,000
6.	Adelaide (AD-U), Australia	1875	———
7.	Brisbane (BRI), Australia	1880	500,000
8.	Auckland (AKU), New Zealand	1883	12,500
9.	Honolulu (BISH), Hawaii	1889	160,000
10.	Rydalmere (DAR), Australia	1890	9,000
11.	Kuching (SAR), Sarawak, Borneo	1895	25,000
12.	Sidney (NSW), Australia	1896	750,000
	II. Founded since 1950 (1951–63)		
1.	Adelaide (AD), Australia	1954	150,000
2.	Alice Springs (NT), Australia	1954	15,000
3.	Laguna (CLP), Philippines	1954	1,000

TABLE 11. Oldest and Youngest Herbaria of Africa.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1900		
1.	Cape Town (SAM), South Africa	1855	———
2.	Cape Town (BOL), South Africa	1867	137,000
3.	Durban (NH), South Africa	1882	89,000
4.	Grahamstown (GRA), South Africa	1889	100,000
5.	Kampala (KAW), Uganda	1898	25,000
	II. Founded since 1950 (1951–63)		
1.	Cairo (CAIH), Egypt	1951	16,000
2.	Lourenco Marques (LM), Mozambique	1951	20,000
3.	Mahalapye (MAH), Bechuanaland	1951	1,345
4.	Salisbury (CAH), Southern Rhodesia	1955	12,000
5.	Dedza (NYAS), Nyasaland	1956	4,500
6.	Elisabethville (EBV), Congo	1956	30,000
7.	Rabat (RAU), Morocco	1957	———
8.	Luanda (LUAI), Angola	1958	12,000
9.	Addis Ababa (ETH), Ethiopia	1959	6,000
10.	Victoria (SCA), Cameroun	1959	1,400
11.	Monrovia (LIB), Liberia	1960	2,500
12.	Nsukka (UNN), Nigeria	1962	———

TABLE 12. Oldest and Youngest Herbaria of South America.

	Location	Year of Founding	Number of Specimens
	I. Founded before 1900		
1.	Rio de Janeiro (RB), Brazil	1808	115,000
2.	Buenos Aires (BA), Argentina	1812	80,000
3.	Santiago (SGO), Chile	1830	68,742
4.	Rio de Janeiro (R), Brazil	1842	350,000
5.	Cordoba (CORD), Argentina	1870	135,000
6.	Belem (MG), Brazil	1871	33,500
7.	Georgetown (BRG), British Guiana	1879	25,000
8.	La Plata (LP), Argentina	1884	220,000
9.	Montevideo (MVM), Uruguay	1890	50,000
10.	Buenos Aires (BAB), Argentina	1899	140,000
	II. Founded since 1950 (1951–63)		
1.	Buenos Aires (IAA), Argentina	1951	600
2.	Paraopeba (PMG), Brazil	1951	6,500
3.	Cruz Das Almas (IAL), Brazil	1952	8,000
4.	Curitiba (IPB), Brazil	1952	5,000
5.	Salvador (BAH), Brazil	1952	2,490
6.	Manaus (INPA), Brazil	1954	13,018
7.	Porto Alegre (BLA), Brazil	1954	2,500
8.	Recife (URM), Brazil	1954	32,000
9.	Buenos Aires (BAFC), Argentina	1955	5,000
10.	Rio de Janeiro (HB), Brazil	1958	25,000
11.	Brasilia (UB), Brazil	1963	20,000

TABLE 13. Largest Herbaria in the World.[1]

Location	Year of Founding	Number of Specimens	Rank by Size	Number of Staff
1. Kew (K), England	1853	6,500,000	1	41
2. Leningrad (LE), USSR[2]	1823	6,000,000	2	34
3. Paris (P), France	1635	5,000,000	3	22
4. Geneva (G), Switzerland	1817	4,000,000	4	5
5. Lyon (LY), France	1925	3,800,000	5	2
[Cambridge (A, AMES, ECON, FH, GH, NEBC),[3] Massachusetts, USA	1864–1923	3,540,150		32]
6. Florence (FI), Italy	1842	3,500,000	6	6
7. Montpellier (MPU), France[4]	1890	3,150,000	7	46
8. Manchester (MANCH), England	1821	3,000,000	8	3
9. New York (NY), New York, USA	1891	3,000,000	8	11
10. Washington (US), D. C., USA	1868	3,000,000	8	21
11. Stockholm (S), Sweden	1758	2,850,000	9	9
12. Vienna (W), Austria	1748	2,500,000	10	9
13. Chicago (F), Illinois, USA	1893	2,350,000	11	5
14. Budapest (BP), Hungary	1870	2,000,000	12	11
15. Edinburgh (E), Scotland	1761	2,000,000	12	12
16. Jena (JE), Germany	1895	2,000,000	12	1

[1] List includes 9 top-ranking herbaria of North America, which together represent 7 different size ranks. Ranking 10th, with 750,000 specimens (size rank 8), is Stanford (DS), California, USA, founded in 1896, with 5 staff members; 11th, with 700,000 specimens (size rank 9), is Cambridge (A), Massachusetts, USA, founded in 1872, with 10 staff members; and 12th, with 675,000 specimens (size rank 10), is Beltsville (BPI), Maryland, USA, founded in 1869, with 8 staff members. The top-ranking Canadian herbarium, founded at Montreal (MT), Quebec, in 1920, is 13th, with 600,000 specimens (size rank 11 for North America) and has 3 staff members; worldwide, MT is the 50th largest herbarium and falls into the 31st size rank.

[2] Figures in *Index Herbariorum* (1964) and other sources (*cf.* Shetler 1967) indicate that the Leningrad herbarium has about 6 million specimens, but more recently the number 5 million is being claimed (Lipschitz and Vassilczenko 1968).

[3] When combined as one, herbaria of Harvard University rank here, but see comments in text under "Size of Collections."

[4] Staff size includes several faculties and is misleading.

TABLE 13. (*Continued*)

Location	Year of Founding	Number of Specimens	Rank by Size	Number of Staff
17. Prague (PRC), Czechoslovakia	1775	2,000,000	12	17
18. Leiden (L), Netherlands	1575	1,800,000	13	30
19. St. Louis (MO), Missouri, USA	1859	1,700,000	14	6
20. Brussels (BR), Belgium	1870	1,600,000	15	15
21. Copenhagen (C), Denmark	1759	1,500,000	16	16
22. Lund (LD), Sweden	1770	1,500,000	16	34
23. Melbourne (MEL), Australia	1857	1,500,000	16	6
24. Munich (M), Germany	1813	1,500,000	16	12
25. Zürich (Z), Switzerland	1834	1,500,000	16	9
26. Cambridge (GH), Massachusetts, USA	1864	1,485,000	17	11
27. Helsinki (H), Finland	1828	1,400,000	18	14
28. Uppsala (UPS), Sweden	1785	1,400,000	18	18
29. Prague (PR), Czechoslovakia	1818	1,300,000	19	3
30. Berlin (B), Germany	1815	1,250,000	20	16
31. Berkeley (UC), California, USA	1872	1,225,000	21	11
32. Paris (PC), France	1635	1,200,000	22	29
33. Cambridge (FH), Massachusetts, USA	1919	1,012,150	23	1
34. Ann Arbor (MICH), Michigan, USA	1838	1,000,000	24	7
35. Bogor (BO), Indonesia	1817	1,000,000	24	6
36. Calcutta (CAL), India	1793	1,000,000	24	11
37. Göteborg (GB), Sweden	1926	1,000,000	24	3
38. Oslo (O), Norway	1863	1,000,000	24	9
39. Philadelphia (PH), Pennsylvania, USA	1812	1,000,000	24	9
TOTAL: 1–17		56,650,000		255
TOTAL: 1–39		85,522,150		531

TABLE 14. Comparison of Geographical Distribution of First 100 and Last 100 Herbarium Foundings.

Continent or Region	First 100 Herbaria (1545–1840)	Last 100 Herbaria (1947–1963)[1]
Africa	0	17
Asia	4	13
Australia	0	3
British Isles	10	2
Central America	0	1
Europe	69	13
Malaysia–New Guinea	1	2
Mauritius	1	0
Mexico	0	2
North America (excl. Mexico)	12	26
Seychelles	0	1
South America	3	15
West Indies	0	2

[1] The "Last 100" really number only 99, because to add one more would have required selecting one from among the 12 founded in different parts of the world in 1946.

TABLE 15. Frequency Distribution of Herbaria by Size of Collection.

No. Specimens in Herbarium	No. Herbaria		Percent Total Herbaria	
	Actual	Cumulative	Actual	Cumulative
0–1,000	19	19	2.6	2.6
1,001–25,000	295	314	40.7	43.3
25,001–100,000	202	516	27.9	71.2
100,001–250,000	102	618	14.1	85.3
250,001–500,000	53	671	7.3	92.6
500,001–1,000,000	20	691	2.8	95.4
1,000,001–2,000,000	20	711	2.8	98.2
2,000,001–3,000,000	6	717	0.8	99.0
3,000,001–4,000,000	4	721	0.6	99.6
4,000,001–6,500,000	3	724	0.4	100.0

TABLE 16. Herbaria with 20 or More Staff Members.

	Herbarium Abbreviation and Location	Number of Staff		Number of Specimens
		Actual	Ideal	
1.	MPU, Montpellier, France	46	67	3,150,000
2.	SP, São Paulo, Brazil	45	2	85,000
3.	K, Kew, England	41	139	6,500,000
4.	LE, Leningrad, USSR	34	128	6,000,000[1]
5.	LD, Lund, Sweden	34	32	1,500,000
6.	L, Leiden, Netherlands	30	38	1,800,000
7.	PC, Paris, France (cryptogams)	29	26	1,200,000
8.	P, Paris, France (phanerogams)	22	107	5,000,000
9.	U, Utrecht, Netherlands	22	7	350,000
10.	BAB, Buenos Aires, Argentina	21	3	140,000
11.	US, Washington, D. C., USA	21	64	3,000,000
	TOTALS	345	613	28,725,000

[1] Probably should be 5,000,000; *see* footnote, Table 13.